Volunteer Monitoring of Water Quality in New Zealand: Where does the Value Lie?

A thesis submitted in partial fulfilment of the requirements for the Degree

of Master of Science in Environmental Science

in the University of Canterbury

by Annabelle Coates

University of Canterbury

2013

Abstract

Natural waterways form an integral part of the urban and rural environment. In New Zealand, their uses are generally related to agriculture, drainage, power generation and recreation, but their value also extends to providing ecological services that are vital to the maintenance of a fully functioning environment. In the areas of the world that are considered to be developed, several functions and services that waterway systems initially would have provided, have been degraded, or lost completely, due to water abstractions, altered flow regimes and input of pollutants.

In New Zealand, and around the world, groups of volunteers give up their time in order to help monitor the quality and state of waterways. However, there remains a distrust of data generated by such groups throughout the scientific community. This concern is also voiced by members of these groups, querying what the point of their monitoring is, if the data has no real use. As a result of this uncertainty about the data quality and its subsequent uses, data is often just entered onto a database with little, or no, analysis conducted.

The purpose of this research was to ascertain the quality of the data generated by volunteers groups in New Zealand by comparing it with data collected by professionals from city and regional councils. Volunteer monitoring methods and tools were also compared with those available to professionals in order to determine if any differences observed were a product of equipment, or other factors. However, data generation is not the only purpose of these volunteer groups. By being involved, volunteers are gaining education, practical skills and knowledge they may not have access to otherwise, and they are meeting people and strengthening community ties. Volunteers from each group therefore also completed a survey to determine their knowledge of the programme they participate in, of the environment and freshwater, and to collect some basic background information. The Styx Living Laboratory Trust (SLLT) in Christchurch, the Wakapuaka Rivercare Group in Nelson and Wai Care in Auckland were the three New Zealand community water monitoring groups chosen to be the subject of this study.

Generally, the volunteer conductivity and pH data was significantly different from that of their professional counterparts, with large differences obvious in the data sets from all three groups. Water temperature was the only variable that was consistently similar for volunteer and professional data. Comparison of the SLLT's methods with professional-level methods, however, revealed that differences in the data sets may be due to a combination of factors including

equipment (e.g., use of pH colour strips instead of meters), and variation in the monitoring protocols, rather than a lack of quality in the volunteer data. However, new dissolved oxygen and nitrogen monitoring methods utilised by Wai Care did produce some promising results, with some of the comparisons unable to be statistically differentiated from the professional data set.

Visual assessment of the SLLT data over time suggests seasonal patterns in pH and conductivity, and possible increases in water clarity over time. Statistical analysis of the individual variables of pH, water temperature, clarity and conductivity, in the SLLT data revealed several significant predictors and interactions, including time, date and pH among other things. However, the very small effect size and the large data set suggest this may just be a product of the large data set with very few of these variable interactions having any real meaning with regards to management.

Volunteers were predominantly over the age of 40, and were generally either very new recruits to their monitoring programmes (<6 months) or had been involved for a reasonably long time (>5 years). There were differing patterns of involvement between the groups with the WRG having volunteers mainly involved for >10 years while the SLLT had a large number of new recruits. There were also varying reasons volunteers chose to become involved however, the predominant reason was concern for the environment.

Approximately half of the volunteers surveyed proved to be very knowledgeable about their programme and understood the purposes of the monitoring programme, although most were associated with a science-related industry and therefore likely already had this knowledge. More education and training would be needed to bring all of the other volunteers up to this level. All volunteers had good knowledge of issues in New Zealand's environment and freshwater currently face, with public apathy considered the most pressing issue.

In summary, despite the lack of clear statistical similarities between volunteer and professional data sets for some variables, the data do not appear to be randomly inaccurate and could be corrected to be combined with professional data. The benefits the volunteers gain appear to outweigh any issues that may be present in the data, as long as the volunteers perceive the data to be ultimately useful. Volunteer-based water quality monitoring has proved to be a valuable way to gather environmental data, educate the community and improve their commitment to local waterways.

Acknowledgments

I have several people I would like to thank who have made the completion of this thesis over the past 18 months possible. Firstly, a huge thank you to my supervisor, Jenny Webster-Brown, for her guidance and suggestions for gathering data and her help perfecting the write up. I would like to thank Chris Phillips (Landcare Research) and Michele Stevenson (Environment Canterbury), both from the Styx Living Laboratory Trust for their help suggesting this research and during the planning stage, and also Michele for her continued support and answering of questions about the SLLT. Thanks must also be given to the Waterways Centre for Freshwater Management for awarding me a scholarship for my studies.

This research could not have been completed without the cooperation of the three volunteer water quality monitoring groups I worked with. I thank every member from the groups that I met and interviewed. It was great to get out and meet the people carrying out the monitoring and making a difference in New Zealand's environment. I must make special note of the volunteers from the SLLT who I have got to know since beginning my research by volunteering alongside them to track the quality of the Styx River in Christchurch. I also must give a big thank you to those people from the other groups who I have liaised with to organise times to meet volunteers and ask questions regarding their groups. Therefore I thank Kathryn Read from Wai Care and Barbara Stuart and Jim Sinner from the Wakapuaka Rivercare Group for their organisation of their volunteers to meet with me. This would have been very difficult without you.

Thanks must also be given to the Christchurch City Council, Environment Canterbury, Nelson City Council and Auckland Council for providing their monitoring data. And also to Professor Eric Pawson from the Geography department and Dr William Godsoe from Biological Sciences for their help with my survey development and statistical analysis respectively.

Finally I must thank my friends and family. I thank my parents for supporting me throughout my years at school and university. Thanks to Mum for slaving through my thesis and other assignments over the years in order to proof read it for me. This is the last time I promise! Also a big thanks to those who I have shared the post grad student room at the Waterways Centre with since the beginning of 2012 for the sounding out of ideas, picking the correct word to use and making long days of work way more fun.

Table of Contents

Abstract .... **i**
Acknowledgments .... **iii**
List of Figures .... **vii**
List of Tables .... **ix**
1 Introduction **1**
1.1 Water Quality Decline: Factors and Causes 1
1.1.1 Natural Causes of Water Quality Decline 2
1.1.2 Urban Water Quality 4
1.1.3 Rural Water Quality 5
1.1.4 Sediment: an Urban and Rural Issue 8
1.2 Water Monitoring Strategies 9
1.2.1 Monitoring for Human Health 11
1.2.2 Monitoring for National Environmental Health 11
1.2.3 Local and Regional Environmental Monitoring 12
1.2.4 Cultural Health Monitoring 13
1.3 Volunteer Monitoring Programmes 14
1.3.1 Volunteer Monitoring around the World 15
1.3.2 Volunteer Water Quality Monitoring in New Zealand 16
1.3.3 Benefits and Barriers in Volunteer Monitoring 17
1.3.4 Data Concerns with Volunteer Monitoring 18
1.4 Research Aims and Objectives 19
2 Methods **20**
2.1 Groups and Catchments 20
2.1.1 Styx Living Laboratory Trust 21
2.1.2 Wakapuaka Rivercare Group 25
2.1.3 Wai Care 29
2.2 Comparison of Volunteer Data to Professional Data 32
2.2.1 Methods Used by Volunteers 32
2.2.2 Methods used by Professionals 36
2.2.3 Date ranges 37
2.2.4 The SLLT Experience 38
2.3 Statistical Analysis 38
2.3.1 Comparison of Professional and Volunteer Data 38
2.3.2 Statistical Tests Used 39
2.3.3 Further Analysis of the SLLT Data 40

2.3.4 Validation of the SLLT Techniques 41
2.4 The Survey 42
2.4.1 Development 42
2.4.2 Survey Delivery 43
2.4.3 Ethics Approval 44
2.4.4 Conducting the Survey 45
2.4.5 Analysis of Survey Data 45
2.5 Quality Control and Study Limitations 47
3 Results 49
3.1 Comparisons of Volunteer and Professional Data 49
3.1.1 Styx Living Laboratory Trust Data (SLLT) 49
3.1.2 Wakapuaka Rivercare Group Data (WRG) 54
3.1.3 Wai Care 58
3.2 Analysis and Trends in the SLLT Data 62
3.2.1 Spatial Trends 62
3.2.2 Temporal Trends 64
3.2.3 Statistical trends 67
3.3 Validation of Volunteer Techniques 68
3.4 Survey Results 69
3.4.1 Demographics 69
3.4.2 Volunteer Involvement 70
3.4.3 Knowledge of Their Programme 74
3.4.4 Opinions of the Programmes 77
3.4.5 Volunteer Knowledge of Environmental Issues 78
4 Discussion 80
4.1 The quality of the volunteer data 80
4.1.1 pH 80
4.1.2 Conductivity 81
4.1.3 Water Temperature 82
4.1.4 Turbidity (and clarity) 83
4.1.5 Dissolved Oxygen 83
4.1.6 Nitrate and Nitrite - Nitrogen 84
4.1.7 Water quality overall 84
4.2 SLLT Data: Trends and Interpretation 85
4.2.1 Spatial Differentiation 85
4.2.2 Temporal Trends 86
4.3 The volunteers: involvement, knowledge and opinions 88
4.3.1 Volunteer Demographics 88

4.3.2 Volunteer Motivations and Barriers 90
4.3.3 How much do the Volunteers Know? 92
4.3.4 Benefits the Volunteers Gain Through Their Involvement 94
5 Conclusions and Recommendations 97
5.1 Conclusions 97
5.1.1 Quality of the data 97
5.1.2 Changes in the Styx River 97
5.1.3 Volunteers 98
5.2 Recommendations 98
5.2.1 For Improved Data Quality 99
5.2.2 For Improved Volunteer Experience 100
5.2.3 For recruitment and maintenance of volunteers 100
5.2.4 Recommendations for the SLLT 101
5.2.5 Recommendations for Further Study 101
6 Reference List 102
Appendix 1: The Survey 114
Appendix 2: LME results 115

List of Figures

Figure 1.1: Biological, chemical and physical forms of water pollution (Spellman 2008). 2

Figure 1.2: Distributions of *E. coli* and DRP in streams located in different land uses (Larned et al. 2004). 5

Figure 1.3: The structure of water quality assessment operations (Maybeck et al. 1996) 10

Figure 2.1: Locations of the volutneer groups taking part in this research 21

Figure 2.2: The SLLT rivers and sites.. 25

Figure 2.3: WRG volunteers prepare to monitor at 'Kahikatea' site on the Wakapuaka River using the SHMAK kit. 26

Figure 2.4: WRG rivers and sites. 28

Figure 2.5: Sites monitored for Wai Care by people who took part in this research 32

Figure 2.6: SLLT volnteers prepare to measure the pH at the Styx Mill Reserve site. 33

Figure 2.7: SLLT volunteers measuring clarity using a clarity tube at Smacks Creek. 34

Figure 2.8: Wai Care volunteers measure DO by comparing the sample with a coloured wheel denoting different concentrations of DO. 35

Figure 2.9: Scouts analyse invertebrate samples under the guidance of a Wai Care volunteer. 36

Figure 3.1: Comparison of the data sets generated by the SLLT and CCC for Smacks Creek 50

Figure 3.2: Comparison of data sets generated by the SLLT and CCC on the Styx River in Redwood .. 51

Figure 3.3: Comparison of SLLT, CCC and ECan data from sites on the Styx River. 52

Figure 3.4: Comparison of data generated in the lower reaches of the Styx River at Brooklands....... 53

Figure 3.5: Comparison of data collected by the SLLT at four sites using their two different methods 54

Figure 3.6: Comparisons of WRG and NCC data collected from the Teal River.................................. 55

Figure 3.7: Comparisons of WRG and NCC data generated at the Lud River site............................... 56

Figure 3.8: Comparisons of WRG and NCC data generated from the Wakapuaka river at Hira........... 57

Figure 3.9: Comparisons of WRG and NCC data generated in the lower reaches of the Wakapuaka River. 58

Figure 3.10: Comparison of Wai Care and Auckland Council Oakley Creek data 2002-2004 59

Figure 3.11: Comparison of Wai Care and Auckland Council NO_x – N for Oakley Creek 2002-2004 60

Figure 3.12: Comparison of Wai Care and Auckland Council Oakley Creek data 2010-2012 61

Figure 3.13: Comparison of Wai Care and Auckland Council NO_x – N for Oakley Creek 2010-2012 61

Figure 3.14: Changes in pH over time, measured between 7am and 7pm at Redwood Springs 3, Styx River 64

Figure 3.15: Variables for selected sites as a function of time. 66

Figure 3.16: Comparison of volunteer measuring methods for pH and conductivity with professional equipment. 69

Figure 3.17: Age demographics across all volunteer groups 70

Figure 3.18: Volunteer occupations across all volunteer groups 70

Figure 3.19: The length of time volunteers have been involved with their monitoring groups 71

Figure 3.20: Reasons volunteers became involved with volunteer monitoring 73

Figure 3.21: What volunteers hoped to achieve when they first became involved across all groups . 73

Figure 3.22: Volunteers opinions across all three groups regarding what the purpose of their monitoring programmes is 74

Figure 3.23: Responses across all groups to whether volunteers consider the data they collect to be of high enough quality to be used by professionals 76

Figure 3.24: Responses to whether the volunteers could name all the parameters they measure at each monitoring occasion. 76

Figure 3.25: Could the volunteers accurately explain what each water quality parameter the measure means?. 77

Figure 3.26: Volunteers opinions across all three groups about the most pressing issues with regard to freshwater in New Zealand. 78

Figure 3.27: Volunteers ideas about the major issues the New Zealand's environment as a whole faces across all three groups 79

Figure 4.1: Children from a Scout group take a break from monitoring to remove a shopping trolley from their monitored stream reach. 91

Figure 5.1: The path to better quality data and a more precise monitoring programme as proposed by this study 99

List of Tables

Table 3.1: Tukey HSD p-values derived from ANOVA comparing each site to all other sites. 63

Table 3.2: Volunteers thoughts about what the data *is used for* (a) and what it *could be used for* (b) 75

Table 3.3: Ideas from the volunteers on how to improve the monitoring programmes 77

1 Introduction

Since New Zealand was first colonised by Europeans in the 19th century, the quality of freshwater has been engaged in a continual decline due to a number of factors including agriculture (Larned et al. 2004, Wilcock et al. 2006, Galbraith & Burns 2007, Monaghan et al. 2007), land use change (Larned et al. 2004, Hamilton 2005, Galbraith & Burns 2007) and increasing levels of urbanisation (Larned et al. 2004, Collier & Clements 2011, Clapcott et al. 2012). In many parts of the world, including New Zealand, monitoring and managing this decline commonly falls to regulatory authorities such as councils and governments. Without actively seeking the collected information, local communities and individuals who are interested in a waterway may remain largely excluded from the process. However, involvement of concerned locals has been found to be an integral factor in the success of natural resource management strategies as demonstrated by Silvano et al. (2005) in their study of the ecological integrity of a small watershed in Brazil. Similar ideas are prevalent in Canada where communities are becoming increasingly more involved with resource management and ecosystem monitoring (Vaughan et al. 2003, Whitelaw et al. 2003, Yarnell & Gayton 2003). This study is designed to assess quality of volunteer based water quality monitoring in New Zealand and to determine the value of such groups with regard to the data generated and the benefits gained by the volunteers.

1.1 Water Quality Decline: Factors and Causes

Despite 75% of the earth being covered with water, only a very small proportion of this is available for use and consumption by humans (Grover 2006). Just 3% of the earth's water is freshwater and of that 3%, most is unavailable for use as it is tied up in ice caps and deep ground water (Shiklomanov 2000, Grover 2006). This leaves approximately 0.003% of the total water on the planet readily available for use by humans in the form of surface water from lakes and rivers (Hussainy & Kumar 2006). As a result of this limited availability and the continual increase in the worlds human population, the amount of the resource available for each person has decreased markedly in recent years (Grover 2006) and this is more pronounced in areas that already experience water stress. Freshwater available for human use can be extracted from two main sources: surface water (lakes and rivers), and groundwater. The quality of each of these sources depends on a number of factors such as geology and surface inputs (Prud'homme 2011).

The tiny fraction of freshwater that is readily available for human use is placed under stress not just from anthropogenic water take requirements (Means et al. 2005), but also from pollutants (Larned et al. 2004, Wilcock et al. 2006, Mallin et al. 2009), development pressures (Larned et al. 2004, Zimmerman et al. 2008), poor governance (Grayman et al. 2012) and economic issues (Zimmerman et al. 2008, Grayman et al. 2012). Currently, freshwater ecosystems may be the most endangered on earth (Dudgeon et al. 2006) as a combined result of these stressors, particularly pollution. Figure 1.1 shows the different forms of water pollution. It can occur naturally as a result of microorganisms, geology and organic decay. However anthropogenic pollution is, in most cases, the overlying issue (Boyd 2000).

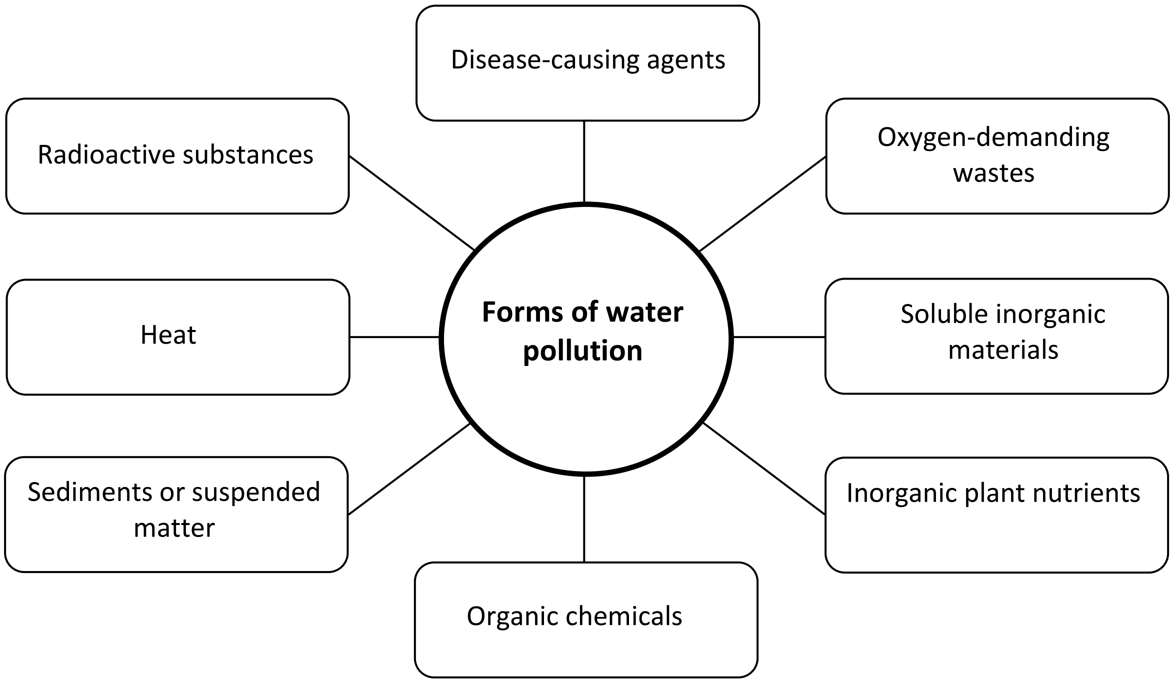


Figure 1.1: Biological, chemical and physical forms of water pollution (Spellman 2008).

1.1.1 Natural Causes of Water Quality Decline

Water quality can be negatively affected by natural means such as climate, geology and topography (Bengraïne & Marhaba 2003, Ministry for the Environment 2007) and the interactions between them. This includes elements such as rock weathering, composition and chemistry of rain water and soils, and chemical reactions between water and soil (Bengraïne & Marhaba 2003). Rainfall is one of the most important natural factors and may become more so as the climate changes. Current research suggests that precipitation levels will decrease in coming decades (Milly et al. 2005, Ministry for the Environment 2007, Kundzewicz et al. 2008), which will in turn affect the quality of freshwater, from both surface and ground sources. Changes in drought frequency alter water flows;

reduced river and stream flows may increase pollutant concentrations indirectly as a result of a lesser dilution of any contaminants that may be present in a waterway. Irrigation will need to increase to maintain the levels of primary production currently being supported which will not only exacerbate issues with stream and river flow but also will increase the amount of leaching and runoff. It is also possible that there will be an increased incidence of algal blooms in waterways because of lower water levels and increased temperatures (Ministry for the Environment 2007). Any management plans designed to regulate the causes of water quality decline must also take into account those natural factors that are outside direct human control.

The assumption is often made, that a stream with physical and chemical variables outside what is considered to be 'normal' or neutral is therefore in a polluted state. However, in some parts of the world, through a combination of natural factors, streams can fall at the limits of a bell shaped curve in terms of physical and chemical measures, yet still support a wide range of pollution intolerant taxa and be completely un-impacted by anthropogenic activities. An example of this can be found with so called 'brown water streams,' which are particularly common on the West Coast of New Zealand and exhibit pH levels considered to be highly acidic in freshwater. In this case, the high acidity is a result of high concentrations of humic substances derived predominantly from decomposing organic matter in swamps and soils (Winterbourn & Collier 1987). Winterborn & Collier (1987) found that species assemblages in West Coast streams were not significantly correlated with stream pH. However, in the northern hemisphere, where acidification of streams occurs as a result of acid rain, pH does affect species assemblages (Clair & Hindar 2005).

The geology of a catchment basin has been demonstrated to significantly affect several aspects of water quality including pH, temperature, conductivity and concentrations of elements and nutrients (Biggs 1995, Kim et al. 1999, Young et al. 2005). A study of the Motueka River, in Tasman Bay, New Zealand, determined that the geology of each study site was a significant determinant for conductivity, pH, turbidity and clarity and also had a strong influence on the yearly thermal regime of the river (Young et al. 2005). Water quality has also been demonstrated to be strongly affected by geothermal and volcanic activity (e.g. Welch 1988, McLaren & Kim 1995, Wang & Milligan 2006). Geothermally derived pollutants such as arsenic (As) and antimony (Sb) directly affect freshwaters in New Zealand's geothermal field such as the Waikato River, draining the Taupo Volcanic Zone (Wilson & Webster-Brown 2009).

1.1.2 Urban Water Quality

Urban pollutants are predominantly produced by human activities including domestic and municipal processes, buildings and building materials, industry, and vehicular traffic. They generally include heavy metals, oils, grease, organic and inorganic compounds, and nutrients (Gnecco et al. 2005). The continual decline of water quality in urban catchments has been attributed to population and history. For example, Tu et al. (2007) found a strong link between the quality of surface water and population density, percentage of land developed and time since the land was developed. This trend has been confirmed by several others (e.g. Interlandi & Crockett 2003, Brett et al. 2005, Schoonover et al. 2005). Clinton and Vose (2006) showed that water quality was lower in an urban reach of stream compared to the same stream under forestry.

Factors influencing water quality in urban environments, that are not such an issue in rural and forested streams, include stormwater runoff (Mallin et al. 2009). Depending on the land use and the intensity of the rainfall, storm water runoff can contain elevated levels of suspended solids, nitrogen, phosphorus, zinc, cadmium, chromium, copper, nickel, lead, polycyclic aromatic hydrocarbons (PAH's), herbicides, pesticides, and industry specific chemicals (Eriksson et al. 2007). Increased stormwater runoff is associated with increasing development as urban areas have larger areas of impervious surfaces including car parks, roads and roofs (Suren & Elliot 2004). Stormwater inputs to waterways can be both point source discharge from a drainage point, and non-point source runoff from surfaces into streams which are more difficult to manage.

Impervious surfaces are also linked to the temperature of waterways (Brabec et al. 2002). Nelson and Palmer's (2007) work on modelling how stream temperatures alter as a result of urbanisation and climate change found stream temperatures could spike up to 7°C following a rainfall event however the temperature of the stream did return to normal relatively quickly. They attributed the reasonably prompt return of stream tempuras to the rapid cycling of stormwater into and out of the stream as a result of high amounts of runoff and therefore short periods of high stream flow.

Microbiological contaminants are also prevalent in urban waterways. Of those rivers that fail to meet water quality standards, 40 per cent do so because of waterborne pathogens (Smith & Perdek 2004). These include faecal bacteria coliforms such as *Escherichia coli* and faecal streptococci, as well as other disease causing pathogens such as salmonella, cholera and hepatitis, and parasites including *Giardia* and *Cryptospordium* (Nash 1993, Paul & Meyer 2001). Microbiological contaminants are a major concern for water managers (Arnone & Walling 2007) due to high level of danger they present to both humans and other animals. These contaminants are generally sourced from human and animal faeces, from infected or carrier individuals, and are transported to urban waterways by stormwater runoff, broken sewerage pipes, sewer overflows and effluents from wastewater treatments works (Smith & Perdek 2004, Arnone & Walling 2007). While issues with biological contamination are more commonly found in developing nations and tropical locations (Nash 1993), they remain an issue for any urban waterway. Figure 1.2 illustrates concentrations of *E. coli* across different land uses. Urban and pastoral land on average has much higher concentrations of bacteria such as *E. coli.* Contamination can arise unexpectedly such as in Christchurch following the February 2011 earthquake when raw sewage was discharged into urban rivers following damage to the wastewater pipe network and the treatment plant.

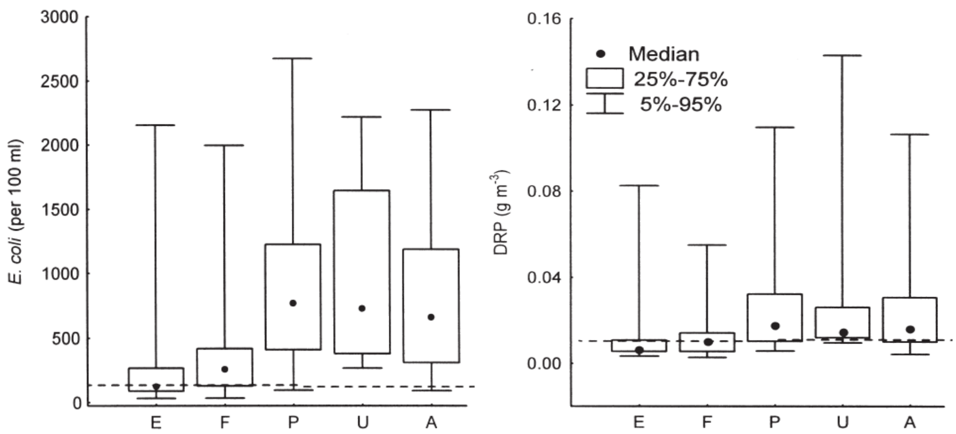


Figure 1.2: Distributions of *E. coli* and DRP (Dissolved Reactive Phosphorus) in streams located in different land uses (E - Plantation forest; F - Native forest; P - Pastoral; U - Urban; A - All classes). Dashed line indicates the guidline values, points are medians, boxes show 50% of site means, whiskers show 90% of site means (Larned et al. 2004).

Another threat to water quality is contamination of water resources from landfill, or other forms of buried waste. This is not an issue that can be identified as solely an urban or rural concern, but affects the area directly surrounding the activity of interest. Many older dump sites are leaching contaminants into groundwater as a result of decay in construction materials, poor construction and poor choice of location with regard to reasonably high water tables (Spellman et al. 2008). These sites can have elevated levels of chloride, organics, nitrate and heavy metals in the groundwater which can therefore make their way to surface water.

1.1.3 Rural Water Quality

Streams and waterways in the rural environment exhibit similar issues with regards to pollution. They experience issues such as eutrophication (Brisbois et al. 2008), nutrient loading (Berka et al. 2001, Brisbois et al. 2008, Lam et al. 2010), bacterial contamination (Rogers et al. 2003, Gannon et al. 2005) and reduced flow due to abstraction for irrigation purposes (Dunn et al. 2003, Cullen et al. 2006). As with urban intensification, as rural land use intensifies (e.g. from low levels of stocking on a high country cattle station to intensive dairying) water quality in the area decreases markedly (Berka et al. 2001, Cullen et al. 2006, Monaghan et al. 2007). Dairying requires greater amounts of fertiliser and pasture growth (Monaghan et al. 2007). This in turn leads to increased amounts of contaminated runoff through fertiliser and faecal contamination, which have been demonstrated to have substantial negative impacts on water quality (Smith & Monaghan 2003, Monaghan & Smith 2004, Monaghan et al. 2007). Cooper & Thomsen (1988) showed levels of nitrogen (N) and phosphorus (P), two crucial components of agricultural fertiliser, were generally much higher in surface waters of catchments used for pasture than forested catchments, a notion supported by Figure 1.2 showing the much higher amounts of dissolved reactive phosphorus (DRP) under pastoral land use compared to forestry. Nutrients also threaten groundwater aquifer use. Costa et al. (2002), Showers et al. (2008) and Suthar et al. (2009) all demonstrated elevated levels of N, above what would be expected to be present naturally, in groundwater in rural areas. This elevation is attributed to infiltration containing nutrients sourced from fertilisers and animal wastes.

In aquifers used to abstract drinking water, N can harm human health by causing methemoglobinemia otherwise known as 'blue baby syndrome' which results in low blood oxygen levels (Knobelock et al. 2000, Costa et al. 2002). Infants are particularly vulnerable in their first six months (Knobelock et al. 2000) and in severe cases, N contamination can lead to death. N from groundwater also has the potential to affect surface waters, especially in spring-fed surface water systems such as the Styx River in Christchurch. As aquatic biota have generally evolved in environments with relatively low levels of N, elevated levels of N resulting from anthropogenic activities reduce their ability to survive, grow and reproduce (Camargo & Alonso 2006). Aquatic animals, including fish and invertebrates, experience symptoms of N toxicity similar to humans with decreased levels of oxygen in the blood (Jensen 2003, Camargo & Alonso 2006).

Nutrients are one of the main problem contaminants in rural waterways and can pose a serious threat to public and ecosystem health (Hooda et al. 2000). Increased application of nutrients, especially fertilisers, leads to increased runoff of contaminants. Elevated levels of these nutrients in waterways can lead to eutrophication, especially in lakes, ponds and other lentic environments and can also occur in rivers (Brisbois et al. 2008). The ecological effects of eutrophication cause low overall quality, and therefore restrict water use with regard to drinking, ecosystem habitat, and other more general purposes (Hooda et al. 2000).

Nutrients in rural waterways are also sourced from livestock manure and organic wastes (Hooda et al. 2000), especially when stock have direct access to streams and creeks. Organic wastes in waterways commonly cause rapid growth of decomposing micro-organisms, which in turn reduce the dissolved oxygen (DO) levels due to a high biological oxygen demand of the bacteria (Hooda et al. 2000). Sudden decreases in DO can stress or kill fish and other aquatic biota (Wang 2005).

As the world's population increases, so does the demand for food production. Areas of land that have been previously considered unsuitable for agriculture and horticulture are now being utilised with fertiliser use on unproductive land, and irrigation of arid land. In the Central Plains Water (CPW) scheme in Canterbury, New Zealand, for example, farmers claim there is plenty of water for everyone but it is not always in the right place at the right time (Rodgers 2009). The CPW is designed to divert water from two major rivers into a reservoir to be used for irrigation. While only minimal impacts to water quality parameters such as DO, temperature, pH and conductivity, are predicted (Dewson et al. 2007), reducing the amount of water in the river channel limits the dilution factor should any contaminants make their way into the waterway (Postel et al. 1996) as well as reducing aquatic habitat. Abstracting water also therefore affects stream biota by altering community composition (Dewson et al. 2007, Miller et al. 2007).

A further issue related to agricultural land use is the disposal of chemicals required for farming including fertilisers and pesticides. A survey of farmers in the US, by Ozkan (1992), found that only 5% of farmers in Nebraska disposed of farm chemicals according to the instructions on the label. The majority of the farmers stored them, diluted then applied them to unused fields, or poured them directly onto the ground. The disposal of the containers chemicals come in also raises concern. While the majority of the farmers interviewed for Ozkan's research expressed concerns regarding the impact chemicals have on the environment, and were willing to support recycling programmes and other methods of safely disposing of containers, others stated that if they could not bury, burn or take pesticide containers to a landfill, they would ignore regulations and dispose of them how they saw fit.

Finally, contamination of rural waterways, particularly groundwater, can occur through septic tanks for residential waste disposal. Septic tanks remove solids from domestic sewage and greywater and disperse this treated water by storage or dispersion into a specified leachfield (Potts et al. 2004). These are frequently used in rural areas unconnected to a municipal wastewater. Reay (2004) determined rural septic tanks to be a significant nonpoint source pollution pathway for bacteria, nutrients and organic matter. As with other forms of subterranean waste disposal or treatment, poor design, materials, site situation and a high water table can all result in a greater release of contaminants to the environment. Also, as septic tanks are generally located in a reasonable proximity to the residence they serve, there is potential for contamination of drinking water supply if groundwater wells are used, as well as contamination of soils irrigated with well water.

1.1.4 Sediment: an Urban and Rural Issue

Another issue affecting water quality as a result of rural and urban land uses is enriched sediment loads. The origin and nature of fine sediment can be highly variable but generally reflects the climate, catchment geology and catchment size (Wood & Armitage). Higher sediment inputs can reduce habitat quality, reduce the lifetime of reservoirs and impoundments, and reduce the aesthetic values of waterways (Quinn & Stroud 2002). Sediment affects more rivers and streams in the US than any other type of pollutant (Parkhill & Gulliver). In extreme cases of sedimentation, fine sediments (of <2mm in size) can smother an entire river bed, significantly altering channel morphology, increasing mortality of aquatic biota, and increasing invertebrate drift (Wood & Armitage 1997). Increased turbidity also reduces the amount of light available for aquatic vegetation for photosynthesis which in turn affects DO and pH. A study conducted by Davies-Colley et al. (1992) found photosynthesis downstream of a sediment input reduced the photosynthetic rate to 27% of the upstream value. As photosynthesising macrophytes and periphyton are an important basal resource for food chains, the effect can be far reaching.

Sediment is also linked to nutrient contamination. Coulter et al. (2004) determined that sediment from rural areas contained significantly higher concentrations of N and P than that of urban and mixed use watersheds. However, they also demonstrated that urban areas were generally the greater sources of sediments, while the rural land was a greater source of nutrients; a pattern supported by Mallin et al. (2009). Mankin et al. 2007 found riparian buffers were effective at removing sediment, N and P from a waterway suggesting focussing on the removal of sediment will also result in reducing nutrient loads. Land use is not the only factor determining sediment load in waterways. As nutrients bind to sediments, deposition of these sediments can change nutrient balances in the affected area. Geology, climate and soil types are other major determinants of sediment in streams (Quinn & Stroud 2002), and therefore need to be taken into consideration when studying sediment and its impacts.

1.2 Water Monitoring Strategies

Monitoring produces the information that managers need to make assessments and decisions regarding environmental state (Yarnell& Gayton 2003). The continued degradation of water resources worldwide has heightened the need for establishing the ambient quality of water bodies in order to quantify changes caused by anthropogenic activities (Strobl & Robillard 2008). With the diverse range of threats to water quality, management approaches must constantly evolve to reflect the changing nature of natural and anthropogenic activities. To reduce the threats and assess mitigation methods, waterways must be monitored.

Parr (1994) identified three main reasons for water quality monitoring; 1) to assess the state of freshwater and the variability of quality; 2) to determine action necessary to sustain and improve quality; and 3) to assess the effectiveness of any action taken. The need for high quality drinking water and water to maintain aquatic ecosystem health has highlighted the importance of having accurate monitoring programmes to monitor the state of freshwater (Ouyang 2005). There are several factors that must be considered when designing a monitoring programme (Figure 1.2). These include developing a clear purpose and aim, identifying what the results need to demonstrate and what resources, in the form of equipment, man-power and funding, are available (Parr 1994). As well as this, the fundamentals of the programme such as when, where, and how, must be considered. Figure 1.2 outlines the main steps and considerations for designing a water quality monitoring programme. Key types of monitoring programmes are described below. Water quality monitoring can be conducted on several different scales depending on the scope and purpose of the programme. For example, trend monitoring is usually conducted at a reasonably low number of sites but occurs regularly and over an extended period of time, and can encompass few or many variables depending on the aims of the programme.

On the other hand, emergency monitoring following an event such as a contaminant spill, occur at a large number of sites, both up and down stream of the contamination site, and measurements are made very regularly but only for a short period of time, targeting only a specific variable such as the contaminant causing the problem (Maybeck et al. 1996). A well-designed water quality monitoring programme identifies issues and established baseline values for long and short term analysis, while at the same time using a cost effective and logical design (Strobl & Robillard 2008). Often monitoring stations can provide data for several different programmes (Maybeck et al. 1996) to reduce costs and provide a more rounded, while still specific representation of water quality. Water quality monitoring may also focus on one aspect of water quality decline such as eutrophication, salinisation or microbial contamination (Strobl & Robillard 2008) with appropriate selection of variables.

In the last century, how the quality of the aquatic environment is assessed has expanded from using a few critical variables, to a level of intricacy that requires simultaneous monitoring of many parameters and how they interact with each other (Maybeck et al. 1996). Additionally, despite the usefulness of templates established from other networks, a monitoring programme will need to be adapted to suit the character of the targeted catchment.

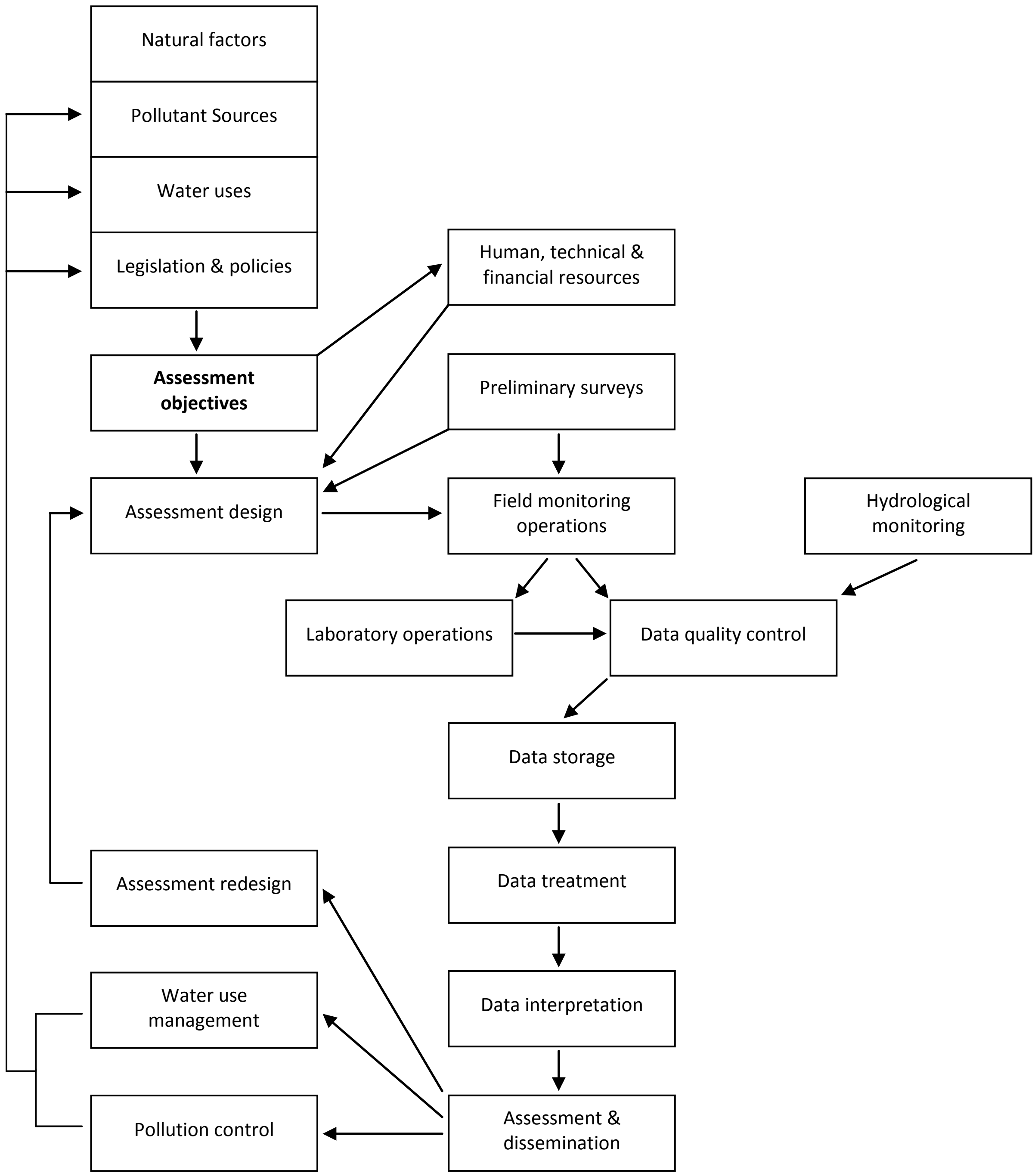


Figure 1.3: The structure of water quality assessment operations (Maybeck et al. 1996)

1.2.1 Monitoring for Human Health

In New Zealand monitoring is routinely undertaken to ensure supplies of drinking water conform with standards set in place to protect human health. The New Zealand drinking water standards identify maximum acceptable values (MAV) for various contaminants including bacteria, protozoa and chemicals (Ministry of Health 2005). As it is sometimes necessary to take drinking water supplies from polluted surface waters, regular monitoring can ensure that treatment is effective and there are no negative effects on human health. Generally, there is a period, which can be from hours to years, over which only a specified number of transgressions is acceptable (Ministry of Health 2005). Monitoring of drinking water in developed countries is stringent with on site laboratory testing of water samples, as well as online continuous measurements of parameters such as turbidity and pH (Van Wezel et al. 2010). Emerging contaminants such as pharmaceuticals and chemicals are beginning to be found in drinking water, and therefore monitoring for them needs to be added (Ritter et al. 2002, Van Wezel et al. 2010).

Techniques for monitoring drinking water include chemical screening for contaminants found in the raw water supply, use of on-line sensors (Ailamaki et al. 2003, Berry et al. 2005), microbial testing, or a combination of two or more techniques (Van Wezel et al. 2010). Sensors are particularly promising as an accurate method for monitoring drinking water quality (Ailamaki et al. 2003, Berry et al. 2005, van Wezel et al. 2010) as they are capable of producing results almost immediately eliminating time taken up with sampling, storage and analysis by more traditional methods.

1.2.2 Monitoring for National Environmental Health

At a national scale, New Zealand also reports on several aspects of environmental health including water quality. This monitoring and reporting is includes Ministry for the Environment (MfE) state of the environment reports (Ministry for the Environment 2007) using data collected by regional and local organisations such as city and regional councils (Ministry for the Environment 2007), the National Institute of Water and Atmospheric Research (NIWA) and the Institute of Geological and Nuclear Sciences (GNS). State of the Environment reporting in New Zealand includes two main groups of indicators: water quality and freshwater demand. Quality monitoring measures concentration of nutrients and bacterial, as well as clarity, temperature, DO and macroinvertebrate richness and is carried out at over 800, mainly lowland, sites around the country (Ministry for the Environment 2007).

In addition, 77 sites are located on 35 key rivers throughout New Zealand as part of the National River Water Quality Network (NRWQN) undertaken by NIWA (Ballantine & Davies-Colley 2010). The combined catchments of the 35 rivers drain approximately 50 per cent of New Zealand's total land area and each river has an upstream 'baseline' site and a downstream 'impact' site (Ballantine & Davies-Colley 2010) allowing for quantification of the impacts development, agriculture and other anthropogenic activities is having on the river. Monitoring programmes targeting water resources not included in the NRWQN are also a vital part of national water quality monitoring in New Zealand. GNS conducts monitoring of groundwater resources in the country as part of the National Groundwater Monitoring Programme (NGMP). They carry out this monitoring in conjunction with regional authorities. NIWA also monitors lake water quality using tools such as LakeSPI which assesses health based on features of selected macrophytes.

Other well established methods of monitoring utilised nationally can be found in the form of biomonitoring or ecological monitoring. It utilises specific species such as invertebrates, fish and aquatic vegetation to give an overall picture of the health of the environment (Parr 1994, Morse et al. 2007). Biological communities can be excellent indicators of the relative health of the freshwater environment they live in as they are sensitive to any changes that may occur. Predominantly, macroinvertebrates are used as indicators of stream health as aquatic plants and algae can be difficult to find and lower densities of fish compared to macroinvertebrates make them tricky to catch and make statistical analysis less robust (Morse et al. 2007). New Zealand has a well established method of determining stream health from the invertebrates present at a site, the MCI. Another macroinvertebrate index commonly used in New Zealand and around the world is percentage *Ephemeroptera*, *Plecoptera* and *Trichoptera* (%EPT). This measures the number of these specific taxa as a percentage of the total taxa present, and like the MCI, the higher the value, the more intolerant the taxa are of pollution and therefore, the better quality the stream is. These indices are used in both scientific study as well as regulatory monitoring due to their all encompassing assessment of waterway health.

1.2.3 Local and Regional Environmental Monitoring

The other sites not within the NRWQN are part of monitoring programmes carried out by local and regional councils and are found both on large rivers and smaller streams (Ministry for the Environment 2007). Monitoring throughout New Zealand's regions occurs for a number of reasons. Regional plans and the Resource Management Act (1991) require the effects of land use and discharges to be monitored to ensure there are no adverse effects on water quality and aquatic ecosystems (Meredith & Hayward 2002, Stevenson et al. 2010). Targeted monitoring is also carried out on specific contaminants identified as being a major issue such as DRP, ammonia-N and faecal coliforms. As a result of the rapid intensification of agricultural land in Canterbury, nutrients in waterways, as already discussed, have been identified as a growing issue requiring monitoring (Meredith & Hayward 2002). Regional and local councils often obtain data from other organisations to supplement the data they gather themselves. For example, in Canterbury, ECan acquire surface water quality data from the CCC as they have an extensive network monitoring waterways within the boundaries of the city of Christchurch (Stevenson et al. 2010). Local and regional monitoring also utilise biological and ecological monitoring as a method of establishing the relative health of a waterway.

Other more localised occasions where monitoring should be carried out are following works in or around streams, following attempts to restore or rehabilitate a water body, and to monitor specific impacts such as the affect of an activity on a smaller sized catchment or monitoring as part of single resource consent. Monitoring of activities and as part of consent compliance can be carried out by the activities coordinating organisation or be contracted out. Monitoring following restoration is a vital component of a restoration project in order to assess if the money spent has been efficiently used and to determine if the desired outcomes, in terms of biotic or physical restoration, have been achieved. However, in spite of the increasing prevalence of stream restoration, the same care has not been awarded to monitoring how these restoration efforts affect the stream long term (Kondolf & Micheli 1995). Monitoring of restoration can include assessments of habitat such as flow velocity, channel stability and the number of runs and riffles, biological assessments (Purcell et al. 2002, Roni et al. 2005), and appraisal of the physical conditions of the water quality (Bash & Ryan 2002).

1.2.4 Cultural Health Monitoring

New Zealand's State of the Environment monitoring is also beginning to include measures of the cultural health of waterways and water bodies. Water holds a special significance for Maori who consider water to have spiritual values and life-giving essence. Therefore existing freshwater management systems, which are based predominantly on technical information, are not always in line with Maori beliefs (Tipa & Teirney 2006). The Cultural Health Index (CHI) has been developed by Ngai Tahu, with the support of MfE (Ministry for the Environment 2007) to allow Maori to assess the health of waterways according to values and traditions important to them. The CHI has three main parts: 1) site status – whether the site has any traditional significance; 2) mahinga kai – the value of the site for mahinga kai (food gathering); and 3) cultural stream health – eight indicators including clarity, flow, and catchment land use which gauge the condition of the site (Tipa & Teirney 2006).

The CHI has been demonstrated by Tipa and Teirney (2003) to correlate well with more technical measures of stream health, such as the Macroinvertebrate Community Index (MCI) and the Stream Health Monitoring Assessment Kit (SHMAK) values. Tipa and Teirney (2003) began their project with the intention of incorporating iwi values into the SHMAK kit. However, they concluded this was not feasible due to the holistic basis of the CHI, compared to the defined parameter measurements of SHMAK. However, when used together, the CHI brings another aspect of stream health to the attention of resource managers, councils and the government and its growing acceptance and use around New Zealand can only improve people's understanding of stream health. It may also possible to adapt its components to suit other indigenous people around the world.

1.3 Volunteer Monitoring Programmes

As environmental issues become more of a focal point for policy makers, politicians and the public, there are individuals who feel motivated enough to do their part in the form of citizen science and community based monitoring (CBM). Yarnell and Gayton (2003) define community based monitoring as "a process whereby non-government organisations, community groups, or individuals participate in long-term monitoring of selected species, habitats, or ecosystem processes with the ultimate goal of improving management of ecosystems and natural resources." It can involve partners such as universities or council authorities, that act as consultants or supervisors of CBM programmes, with the intention of ensuring programmes are carried out safely and accurately. CBM is generally carried out by people who would not normally have any part in environmental monitoring; although members of voluntary groups can include professionals from environment related industries who want to be involved with their community. Programmes are strengthened by people such as these who provide their expertise in environmental monitoring, state or processes.

Monitoring water quality can be undertaken by volunteers who do not have a background in water quality monitoring. While detailed chemical analysis of water may remain outside scope of community monitoring programmes, use of biotic indices can suffice for the purpose of establishing the relative health of a particular waterway. Volunteer environmental monitoring is certainly not a new concept, having been in use for more than one hundred years. Since 1900, volunteers across the United States have taken part in an annual bird count at Christmas (Audubon 2012) and the numbers of volunteers taking part is now up to 80,000 people each year (Cohn 2008).

1.3.1 Volunteer Monitoring around the World

Volunteers are a well utilised and necessary part of water quality monitoring around the world. This idea that volunteers can conduct monitoring of water quality is growing in popularity around the world with many groups already established in areas such as the United States (Svendsen & Campbell 2008), Canada (Donald, 1997, Whitelaw et al. 2003, Yarnell & Gayton 2003, Sharpe & Conrad 2006) and Australia (Cuthill 2000, Warburton & Gooch 2007) and popularity is continuing to increase.

In their review of CBM in British Columbia, Canada, Yarnell and Gayton (2003) identified three main reasons for establishing and supporting CBM programmes: 1) effective environmental management remains limited by where and how often monitoring can be undertaken; 2) there is growing public pressure for responsible management of all components of the environment; and 3) the public, including concerned citizens and environmental enthusiasts for example, are often interested in helping to collect ecological information. It has also been encouraged in other parts of Canada, such as Nova Scotia, as a method to fill the gaps left in monitoring networks as a result of funding cuts (Sharpe & Conrad 2006). Similarly, Australians over the age of 55 contribute $74.5 billion (Australian) on an annual basis in the form of volunteering activities (De Vaus et al. 2003, Warburton et al. 2007).

The United States is another country where CBM is becoming an integral part of community education, training and environmental monitoring. The US Environmental Protection Agency (EPA) plays in important role in the US's volunteer programmes, sponsoring conferences bringing together volunteers and stakeholders, managing a database of volunteer coordinators and publishing manuals pertaining to volunteer monitoring planning, implementation and methods. The more populous states of California and New York have close to 100 separate CBM programmes, each focusing on some aspect of water registered with the EPA's database. Despite the large number of existing groups, the EPA encourages people to start their own group if they cannot find one close enough to them, or of interest to them. These initiatives help grow the CBM network in the US, to the benefit of the community and the environment.

1.3.2 Volunteer Water Quality Monitoring in New Zealand

New Zealand is often promoted as one of the cleanest and greenest countries in the world, thanks to tourism campaigns that promote native forests, mountains, rivers and beaches. New Zealand has a high level of environmental activism and environmental issues have a high profile, in the media and with the government. Environmental lobby groups prevalent throughout the country include the Royal Forest and Bird Society of New Zealand and the Environment and Conservation Organisation of Aotearoa New Zealand (ECO), as well as political parties such as the Green Party of Aotearoa New Zealand. There are also smaller lobby groups with specific interest in water quality such as Waterwatch and SWIM. Waterwatch operates globally with a few chapters operating in New Zealand. In Christchurch, the programme in run in conjunction with Lincoln University and provides schools, and other groups, with equipment and information about monitoring waterways. The programme is more prevalent in Australia where it was established by the Australian Government in 1993 and now is made up of almost 3000 groups (Australian Government 2007).

Other groups include the Styx Living Laboratory Trust (SLLT), the Wakapuaka Rivercare Group (WRG) and Wai Care. These groups focus on water quality in a specific catchment or region and were all established around the year 2000. There are other organisations that operate throughout the country that provide information to land owners and communities and participate in monitoring for a specific project. The Landcare Trust, established in 1996, to encourage farmers and land owners to improve their land management practices (Landcare Trust 2013). They oversee various projects around New Zealand, many with an emphasis on water. For example in Nelson, recently completed projects include the Sherry River Project; improving water quality through farm environmental planning, and Aorere Rai Project; farmers as leaders in water quality action. Both projects have monitored water quality however, they only operated for a fixed period of time.

In New Zealand, the Resource Management Act 1991 is the overriding legislation governing the use of freshwater resources, but is not a piece of law lay people access or use on a regular basis. Unless individuals are aware of notified or partially notified consent applications, such as a large project that gets media coverage, they can be excluded from the process. Regionally, freshwater resources are also governed by Regional Plans, again, a document the public may not be aware of or know how to access it. CBM can be useful for including the community in the governance and control of a local water resource.

1.3.3 Benefits and Barriers in Volunteer Monitoring

The value of community environmental monitoring does not just lie with the scientific data it generates, but has long been recognised as having a high educational value (Bjorkland & Pringle 2001, Nicholson et al. 2002) and involving the community in environmental issues may help address any issues. Volunteer monitoring is also recognised in the United Nation's Agenda 21 (United Nations 1993) which recommends that local communities should be consulted and included in making decisions about the uses of local natural resources. Al Gore (1992), in his book *Earth in the Balance*, stated "free men and women who feel individual responsibility for a particular part of the Earth are, by and large, its most effective protectors, defenders and stewards." By including local communities in the decision making process, design and implementation phases of a CBM programme, they gain knowledge and a sense of power that enables and encourages them to take charge of their environment including its uses and values (Cuthill 2000). There is the potential for significantly more CBM groups to establish in both the developed and developing world, however, at least one person has to take the initiative to set one up.

Once established, however, volunteer CBM groups can face barriers including the retention and recruitment of volunteers. Reasons for people not giving time to voluntary groups such as CBM depend on interests, family and work commitments. Despite people's apparent growing concern for the environment, and 2002 study found 49% of Australians cited "no time" as the reason they are not involved in any voluntary work (Christie 2004). Another theme is fear of commitment. Other reasons include cost of travel to volunteer, lack of enthusiasm to learn new skills and fear of commitment (Warburton et al. 2007), lack of support from friends and family (Kulik 2007), the ease with which hard work by volunteers can be undone or judged (Warburton & Gooch 2007) and that existing volunteers did not make new volunteers feel welcome (Warburton et al. 2007). Warburton et al. (2007) also noted that barriers to volunteering are generally assumed rather than being based on actual experiences.

Despite these barriers, Warburton et al. (2007) found that in general, incentives to volunteer outweighed the barriers. Incentives included a greater sense of fulfilment, increased perceived health, helping to keep retirees busy and giving them a 'sense of purpose', becoming more involved with the community, passing on knowledge and skills to a younger generation (Warburton & Gooch 2007). Other studies confirm a sense of increased knowledge, skills and social interaction that results from working with others in a volunteer organisation (Christie 2004). Incentives, as with barriers, tend to vary depending on specific volunteers and their opinions, experiences and information they have about the programme they are involved in, or potentially involved in.

1.3.4 Data Concerns with Volunteer Monitoring

Despite the increasing pressure to incorporate volunteer generated data into regulatory and management framework, concerns have been raised about the accuracy of this data (Engel & Voshell 2002). Concerns focus on inconsistencies in sampling techniques, levels of training (Penrose & Call 1995), and equipment available for use. To date, there have been only a limited number of studies that have compared volunteer data to professional data in order to assess the relative accuracy. Most have assessed macroinvertebrate monitoring programmes, and focused on the volunteer's ability to accurately sample and identify macroinvertebrates (Penrose & Call 1995, Fore et al. 2001, Nerbonne & Vondracek 2003, O'Leary et al. 2004). Some assessed volunteers opinions and knowledge of the programme they are involved in (Overdevest et al. 2004)

Fore et al. (2001) demonstrated that volunteer collected macroinvertebrate data, and data collected independently by professionals were highly correlated, with results differing very little. However, volunteer monitors were less able to extract and distinguish invertebrates from the collected sample, retrieving only 85% of the invertebrates from samples, and in general, identifying fewer taxa than professionals. Water quality data collected by volunteers from Waterwatch Victoria in, Australia, was compared with professional data collected as part of the Victoria Water Quality Monitoring Network (Nicholson et al. 2002). Few significant differences between the volunteer and professional data were found. These examples, along with others (Canfield et al. 2002, Gouveia et al. 2004) support the continued use, and expansion of volunteer monitoring programmes.

However, there remains a distrust of volunteer data within the scientific community (Conrad & Hilchey 2011). Gouveia et al. (2004) and Bradshaw (2003) have both suggested that citizen science data is not taken seriously by people in decision making and scientific roles, because of concerns raised about volunteer data lacking credibility, completeness and the ability to be integrated into professional data sets. A monitoring programme must remain robust and consistent over time, something that may not be possible with the frequent turnover in volunteers. The level of training of volunteers has also been cited as a reason for not trusting volunteer macroinvertebrate data due to a high prevalence of both false positive and false negative data specifically in the case of identification of species (Royle 2004). Confidence in the partiality of the data has even been questioned by the US Congress, who in 1994, requested the National Biological Survey exclude all data generated by volunteer groups due to the belief in Congress that the volunteers may have an "environmentalist agenda," that would result in biased data collection and reporting (Conrad & Hilchey 2011).

1.4 Research Aims and Objectives

It is the purpose of this study to determine the value of community group participation in waterways monitoring in New Zealand, particularly with regard to the scientific value of the data generated, educational gains, engagement in environmental issues, and involvement within the community. This study was initiated when members of the SLLT, a CBM water quality group in Christchurch, New Zealand, expressed concern regarding the quality of their data, and worried that it may not hold up to rigorous scientific assessment (pers. comm. Chris Phillips, Landcare Research, 2011). They have voiced opinions regarding data accuracy especially due to variability in methods used by different volunteers to collect data and in the analysis that is conducted. They have also asked why they monitor if the CCC and Environment Canterbury (ECan) also monitor the river. In order to maintain volunteer enthusiasm and to help recruit new volunteers, they must perceive that there is a point to what they are doing and that therefore they are making a difference.

The research has the following objectives;

1. To identify three representative volunteer monitoring groups in New Zealand to take part in the study;
2. To establish the quality of the volunteer data by comparing it to professional data collected on the same river and over the same time period;
3. To engage with these volunteer water quality groups to gather information about volunteer knowledge, opinions and the design and protocols of each monitoring programme;
4. For one CBM group to undertake more detailed study of the water quality data and practices and report significant findings back to the coordinator and the volunteers of the group;
5. To determine the benefits the volunteers gain by being involved; and
6. To recommend changes aimed at getting the best environmental outcomes for such community groups, from both data quality and community perspectives.

2 Methods

This study was carried out in three main parts. The first part involved approaching volunteer groups and city and regional councils to obtain their data for comparison. These data sets were then compared where sites were in corresponding locations to determine if there were any similarities or differences between professional and volunteer generated data. The second part of the study engaged with one of the volunteer groups on a more intimate basis. For this group, their data set was analysed for any trends or changes in the water quality parameters over time and their monitoring methods and equipment were evaluated for accuracy while the author was participating in monitoring events. The final part of the project involved interviewing volunteers from all groups in order to determine their involvement, knowledge and thoughts about volunteer water quality monitoring.

2.1 Groups and Catchments

Selection of the volunteer monitoring groups to work with, as well as the SLLT, began with research into what groups were operating in New Zealand. Several groups were approached via email to enquire as to the activities that their volunteers carried out. Finding groups that actively engaged in monitoring water quality on a regular basis proved to be a reasonably difficult endeavour, as most of the groups approached only carried out community plantings and had periodic information evenings and meetings to discuss the goings on in relation to their particular environment. An internet search was also conducted which returned some promising results including Waterwatch Wellington and SWIM (Safe Water Information Monitoring) on Banks Peninsula who were both described as having volunteers carry out regular water quality monitoring at several sites in their specific locations. Further investigation into these groups however, revealed they were no longer operating. SWIM had recently stopped their monitoring programme while Waterwatch in Wellington had ceased to operate longer ago. When contacted about Waterwatch, no one at the Greater Wellington Regional Council appeared to know anything about the Waterwatch programme.

Through a combination of internet, city and regional council searches, and referrals from people contacted, three groups were identified as being appropriate to accompany the SLLT as the focus groups for this research. There were Wai Care in Auckland, the Wakapuaka Rivercare Group in Nelson and Operation Patiki in Hastings. Permission had already been received from the SLLT to work with them, and permission was sought from the other groups. These groups were approached using email and telephone calls to introduce the project and explain the purpose of the research and what would be required if they allowed me to work with them. Despite efforts to contact Operation Patiki to arrange a date to travel to Hastings to conduct the interviews and questionnaire, calls were not returned after the initial contact so, unfortunately, the number of groups participating in this research was reduced from four to the three located in Auckland, Nelson and Christchurch (Figure 2.1).

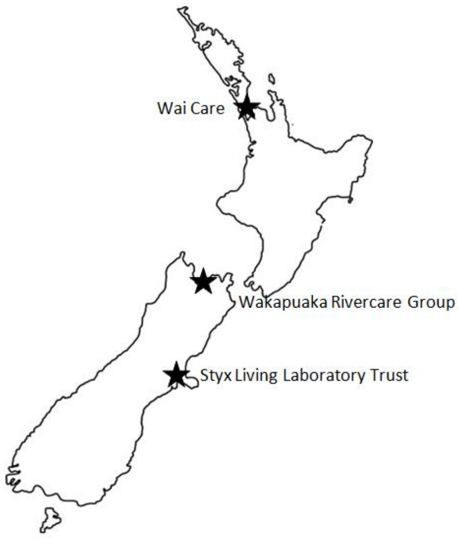


Figure 2.1: Locations of the volutneer groups taking part in this research

2.1.1 Styx Living Laboratory Trust

History and Nature of the SLLT

The SLLT was established in 2000 following two years of consultation and planning, and developed a long term plan for the Styx River catchment which has been implemented by members of the community and local authorities. This plan, identified as ‘The Styx Vision 2000 – 2040’, aims to build on, and to protect specific values connected to the Styx River and its environs via five main objectives (Styx Living Laboratory Trust 2013 a):

Vision 1: To achieve a "Viable Springfed River Ecosystem" to complement the other representative protected ecosystems of Christchurch such as the Port Hills, Travis Wetlands and the Coastline.

Vision 2: To create a "Source to Sea Experience" through the development of an Urban National Reserve.

Vision 3: To develop a "Living Laboratory" that focuses on both learning and research as practised by Dr Leonard Cockayne (1885).
Vision 4: To establish "The Styx" as a place to be through maintaining and enhancing the special character and identity of the area.
Vision 5: To foster "Partnerships" through raising the quality of relationships as we move forward together.
Each of these visions is accompanied by key goals, directions and proceedings to put them into practice. The Christchurch City Council (CCC) adopted the Styx Vision 2000 – 2040, and has obtained large sections of land that are adjacent to the Styx River and its tributaries as they become available. Eventually, this land will be re-established as habitat for wildlife and will form a network of green corridors from the river source to the sea. The five visions are based on a series of issues that have been identified by locals and professionals alike as matters of importance for the catchment.

The Styx catchment has been extensively modified since it was first settled by Europeans in the 1850’s with its surrounding land being part of several early Canterbury runs and being the site of several different types of mills including flax, flour and sawmills (Hills & Hills 2006). Later on, the land was utilised by fruit growers, market gardens and other agriculture, and more recently for continued urban development including subdivisions such as Northwood, Regents Park (Hills & Hills 2006) and the soon to be developed Prestons and Highfield Park subdivisions. The main issues identified in the Visions are all related to the change in land use since the 1850’s and include changes to ecology, drainage, heritage (both Maori and European), landscape, and the preservation of Maori culture in the area (Styx Living Laboratory Trust 2013 b).

Under Vision 3 of the Styx Vision 2000 – 2040, research and learning programmes have been established supporting the community and local school teachers and tertiary students. The Trust offers summer scholarships to tertiary students who undertake a research project, during the summer university holidays, on a specified topic of importance to the Styx catchment. It also supports local teachers through the Royal Society Teacher Fellowships to gain practice and experience in technological, scientific or social sciences. Another important aspect of the Trust under Vision 3 is the establishment of a CBM programme specifically looking at the quality of the water in the Styx River and its main tributaries. Currently, the SLLT has two separate CBM programmes being carried out, one focusing on water quality, and the other on invertebrates.

Monitoring for the invertebrate programme is carried out twice per year, in spring and in summer, at eight sites spanning the Styx River and its two main tributaries, Smacks Creek and the Kaputone Stream. At each monitoring session invertebrates are sampled and assessments are made of the overall habitat including substrate and aquatic and riparian plants. Invertebrate samples are then identified and numbers recorded allowing for the development of a picture of the overall health of the different sites, and are therefore able to provide a reasonably representative picture of the health of the entire catchment. Water quality monitoring occurs monthly at ten sites across the Styx catchment using the SHMAK kit. The main measurements taken are for pH, water clarity, conductivity and water and air temperature, however visual assessments of substrate, riparian vegetation and bank stability are also recorded. This monitoring is carried out entirely by volunteers however guidance is provided by professionals from local government and from the private sector.

Catchment Characteristics

The SLLT works on the Styx River, in the north of Christchurch, New Zealand. The Styx River, a lowland river, drains a catchment of approximately 50 square kilometres and flows in a roughly north east direction from an area bordered by Harewood, Wooldridge, Wairakei and Stanleys Roads, shown on Figure 2.2, for over 24 kilometres before it flows into the Brooklands Lagoon and then out into Pegasus Bay. Its channel lies in a former channel of the Waimakariri River (Hills 2002, Forsyth et al. 2008) and the catchment substrate is predominantly made of grey river alluvium comprising of silt, sand and gravel in relatively active flood plains, and of beach sand from remnant shorelines (Institute of Geological and Nuclear Sciences 2008). At its source, it is a dry swale that only sporadically flows as a result of high rainfall however flow establishes relatively quickly and it is fed along its source from a network of 13 springs (Hills 2002) that are part of the Waimakariri system. The main tributary of the Styx River is the Kaputone Stream. The Kaputone, also spring fed through its length, flows from near the corner of Johns Road and Groynes Drive to the east in a meandering path of approximately ten kilometres before it joins the Styx River at the corner of Marshland and Lower Styx Roads. There are several other smaller tributaries that flow into the Styx River, the largest of which is Smacks Creek. This creek is approximately 1.75 kilometres long flowing east through Willowbank Wildlife Reserve into the Styx River in the Styx Mill Reserve.

Of these waterways, only the Styx River is gauged with ECan and CCC locating two monitoring sites on the river. One site is at Radcliffe Road upstream of its confluence with the Styx River. This site shows that over the last 12 months, the river has had an average flow of around 1.5 cubic metres per second (cumecs) with peaks of between three and seven cumecs for high flow events

(Environment Canterbury 2012). The second site is at Harbour Road near the mouth of the river and at this site, only the stage height is measured. This site is heavily influenced by the tide with some cases where the flow of the river appears to be in an upstream direction. Stage height here varies between around nine and ten metres and is not affected significantly by high rainfall events (Christchurch City Council 2012). The installation of tide gates just downstream of Harbour Road does help to limit the effect of tidal variation on the lower reaches of the river.

The catchment is predominantly rural used for grazing, market gardening and lifestyle blocks. However, a large portion of the western catchment is under urban development and there are also small sections of business and industrial development. Within the catchment is the Kainga Forest, parts of Bottle Lake Forest, both commercial plantation forests, and the Styx Mill Conservation Reserve. The land the reserve (60 Ha) now occupies was originally purchased in the early 1970's by the Waimari County Council, now part of the CCC (Styx Living Laboratory Trust 2013 c). The reserve is now in the process of having a predator proof fence erected around its perimeter with the hope this will exclude large mammalian predators such as cats and dogs from the reserve in an effort to bolster populations of native birds and reptiles that are currently found within its habitat. The river also holds recreational value for many of Christchurch's residents. The walking track in the Conservation Reserve is popular along with the lower reaches, which are enjoyed for walking, whitebaiting and fishing.

Study Site Choice

The SLLT monitor ten, ten metre reaches on the Styx River (Figure 2.2). Two of these are located on Smacks Creek, two on Kaputone Stream and the rest on the mainstem of the Styx River. CCC monitors eight sites, one on Smacks Creek, two on Kaputone Stream and the rest on the Styx River. ECan only monitor one, a site in the lower part on the Styx River which is incidentally at almost the exact same location as one of the CCC sites. ECan are considering ceasing this monitoring as the CCC has the river well covered (Michele Stevenson, ECan, pers. com.). The sites monitored have been largely chosen due to ease of access with all being accessible through public land, reserves or with express permission of land owners. The site at Everglades Golf Course is the only site not accessible through public land or a reserve.

The sites chosen where volunteer and professional data could be compared needed to be located very close to each other, such as the SLLT's Smacks Creek and the CCC's Smacks Creek at Gardiners Road (1 and A on Figure 2.2 respectively). Where the sites were located a distance from each other, as in the case of the lower reaches, one site upstream, and one site downstream were used as comparisons. For example, CCC's Richards Bridge (G) and ECan's Teapes Road (i) sites were compared with Radcliffe Road (7) and Brooklands (10) from the SLLT. These sites were used as the lower reaches are reasonably homogenous with no major spring or tributary inputs.

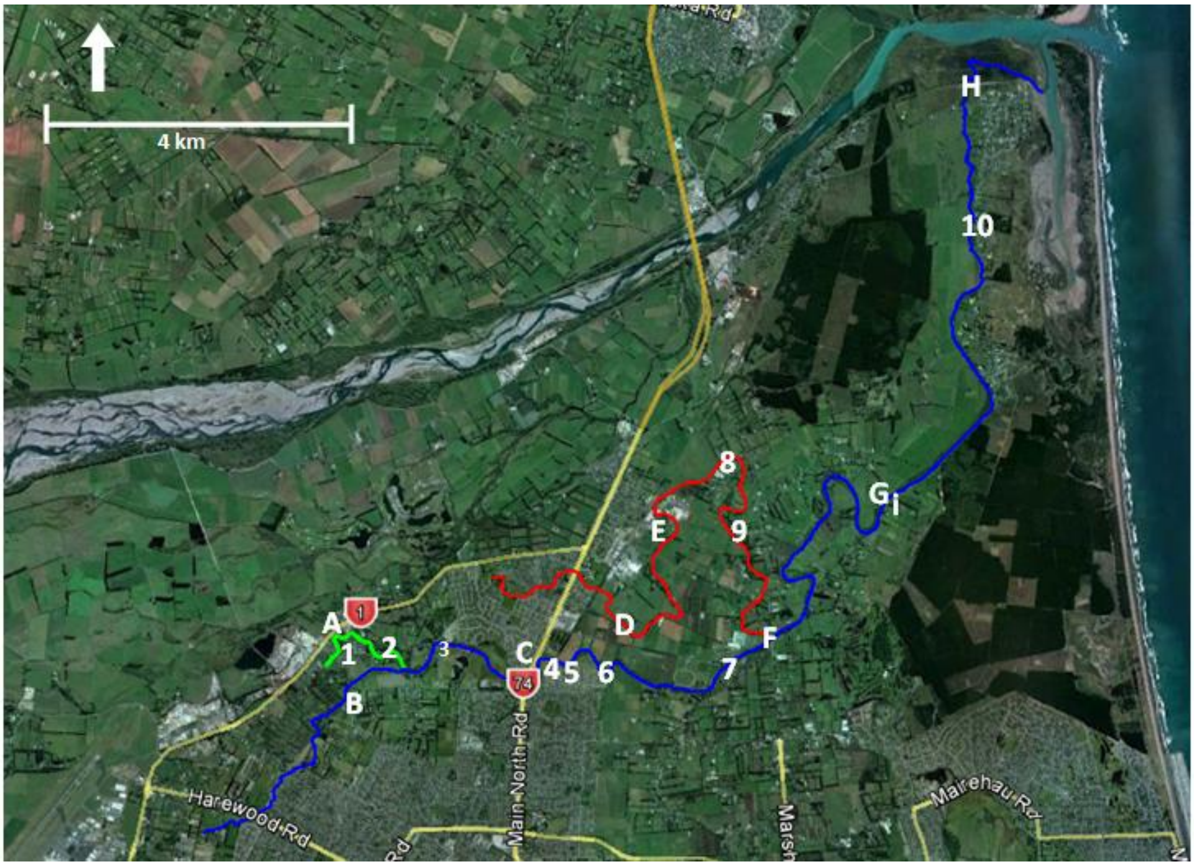


Figure 2.2: The SLLT rivers and sites. Blue – Styx River; Red – Kaputone Stream; Green – Smacks Creek; Numbers = SLLT sites (1 – Smacks Creek; 2 – Willowbank; 3 – Styx Mill; 4 – Redwood Springs 1; 5 - Redwood Springs 2; 6 - Redwood Springs 3; 7 – Radcliffe Road; 8 – Ouruhia Domain; 9 – Everglades Golf Course; 10 – Brooklands), Letters = CCC sites (A – Smacks at Gardiners Road; B – Styx at Gardiners Road; C – Main North Road; D – Kaputone at Blakes Road; E – Kaputone at Belfast Road; F – Styx at Marshland Bridge; G – Styx at Richards Bridge; H – Styx at Harbour Road Bridge), and Roman Numerals = ECan sites (i – Teapes Road).

2.1.2 Wakapuaka Rivercare Group

History and Nature of the WRG

The Wakapuaka River, situated to the northwest of Nelson is the third group to take part in this research. Like the SLLT, the WRG focuses on just one river and its catchment. Joined by four main tributaries, Slater Creek, Teal River, Lud River and Pitchers Stream, the Wakapuaka flows from the Bryant Ranges into the Delaware inlet and out through Cable Bay and Delaware Bay. The Wakapuaka Rivercare Group established in 1999 by members of the local community who were concerned about the state of the river and where its quality and value might be heading in the future. Its members include local land owners, Hira School staff and students and other interested volunteers from the Nelson area. The river and catchment have a wide range of uses with water being extracted from the Wakapuaka, Teal and Lud Rivers for domestic water use and for irrigation, and the river also has educational, recreational and habitat values. The WRG enlisted the help of NIWA, Fish and Game and the NCC in order to identify and establish sites suitable for monitoring in the catchment. Some sites have changed over the years as the river has altered its course and some have ceased to be monitored as numbers of volunteers fluctuate, however at least five sites are still regularly monitored. Like the SLLT, the WRG use the SHMAK kit as the basis of their monitoring (Figure 2.3).

The Wakapuaka River flows adjacent to the township of Hira and is just across the road from Hira School. The school is involved with the WRG taking charge of monitoring one of the sites situated across the road from the school. Their involvement has allowed the students to experience hands on learning about fresh water quality and ecology, and for them to watch how the river changes in their time at the school. Hira School has also established a native plant nursery and provides seedlings for free to local property owners to plant in their gardens and also uses these plants in riparian planting projects they have been involved in throughout the catchment.

Figure 2.3: WRG volunteers prepare to monitor at 'Kahikatea' site on the Wakapuaka River using the SHMAK kit.

Catchment Characteristics

The WRG work in the Wakaupaka catchment, located north east of Nelson. The Wakapuaka River drains a catchment of over 65 square kilometres originating near the Whangamoa Saddle in the Bryant Range (Sheridan 2007). The Wakapuaka itself flows in a primarily northerly direction and is approximately 16 kilometres from source to sea but has several tributaries that join it throughout its length before it reaches the sea via the Delaware Inlet, Cable Bay and Delaware Bay (Figure 2.4). It is fed primarily by runoff and from the four main tributaries: Slater Creek, Teal River, Lud River and Pitchers Stream. Slater Creek joins the mainstem furthest upstream while Pitchers Stream is furthest downstream. The Tasman District Council (TDC) has one river discharge monitoring station located on the Wakapuaka River at Hira. The river has an average flow of 1.75 cumecs but does fluctuate depending on the time of year. The river is also prone to flooding with the most recent major event occurring in January 2012 which caused significant damage to land and roads as a result of high flows. The largest flood flow recorded for the Wakapuaka occurred in February 1995 and measured a maximum value of 204.3 cumecs (Sheridan 2007, Tasman District Council 2012).

The geology of the catchment is heavily influenced by the Waimea Fault which extends from the Nelson Lakes area in the south, north to Taranaki. This fault provides a clear distinction between the two main rock types in the area. The bedrock of the Wakapuaka valley is predominantly 'Brook Street Volcanics' which is primarily responsible for the valleys fertile soil (Sheridan 2007, Institute of Geological and Nuclear Sciences 1998). On the eastern side of the fault, the bedrock is mainly that of the 'Maitai Group' (Sheridan 2007) predominantly comprised of sedimentary rock including mudstone, sandstone and limestone (Institute of Geological and Nuclear Sciences 1998).

Within the catchment are three main land uses. In the lower part of the valley the river meanders on relatively flat coastal alluvial plains and is predominantly under agriculture. This part of the catchment does have some small areas of remnant native forest with the largest stand found on the edge of the estuary at Delaware Inlet while single mature kahikatea and totara trees are dotted here and there throughout the alluvial plain (Sheridan 2007). The other less steep areas in the catchment such as in the Lud Valley and the lower parts of the Teal Valley are utilised by lifestyle sized properties. The steeper parts of the catchment are under both plantation forestry and natural bush. Only a small amount of water from the Wakapuaka River is abstracted for stock purposes while the tributaries are relied upon for domestic drinking water as well as being utilised for irrigation and stock water. The river also holds recreational values for locals and visitors alike, with it being utilised for fishing, whitebaiting, bird watching and swimming (Sheridan 2007).

Study Site Choice

Since its inception in 1999, the WRG has monitored several different sites of ten metres in length throughout the catchment. However, many of these are no longer monitored due to a lack of volunteers and the river changing its course. The sites still regularly monitored are Teal River, Hira shop, Kahikatea, and Woolshed with the Lower Lud still monitored occasionally (Figure 2.4). Originally each site was monitored six times per year however it now only occurs once per season at the sites still in use. The Nelson City Council (NCC) monitors seven sites throughout the catchment, four of which are on tributaries. As with the SLLT, sites are all easily accessible either through public land, road access or with permission of the land owners. As the Wakapuaka River is prone to changing its course in the lower reaches, there has been some minor relocation of sites if sites have become unsafe to monitor.

The sites used to compare professional and volunteer data were chosen for two reasons. Firstly, the sites compared represented four of the sites still monitored regularly by volunteers and therefore had the most expansive data set and second because they were close to their professional or volunteer counterpart.

Figure 2.4: WRG rivers and sites. Blue – Wakapuaka River; Red – Teal River; Green – Lud River. Numbers = WRG sites (1 – Teal River; 2 – Lower Lud; 3 – Hira Store; 4 – Woolshed; 5 – Kahikatea), and letters = NCC sites (A – Lud at 4.7km; B – Teal at 1.9km; C – Lud at SH6; D – Wakapuaka at Duckpond Road; E – Wakapuaka at Hira; F – Pitchers Stream at 890m; G – Wakapuaka at Maori Pa Road)

2.1.3 Wai Care

History and Nature of Wai Care

Wai Care was first established in 2000 by the North Shore, Auckland, Manukau and Waitakere City Councils and the Auckland Regional Council and was joined in 2004 by the Rodney and Papakura District Councils. Following the amalgamation of the councils in the Auckland area in 2010, Wai Care is now delivered across the entire Auckland Region by the Auckland Council. The programme endeavours to work with individuals, communities, schools, families and organisations to help to improve stream and catchment health across the Auckland region. While the programme is not as specific as the SLLT focus on one river, a Wai Care co-coordinator works with groups to establish and run their own monitoring programme on a river or stream of their choice. The group can chose where, what and how often to monitor with support, education, awareness and training provided by the co-ordinator. Each group is responsible for uploading the results of a monitoring session to the Wai Care website which can be accessed by several other landcare groups and organisations including universities, councils and government agencies such as the Department of Conservation and Landcare Research.

Wai Care is an action based programme that is established on the belief that prevention is better and more positive than a cure. The ultimate goal of Wai Care is to "restore waterway health; reducing the effects that people have on waterways as much as possible and taking steps to rehabilitate waterways damaged by our day to day activities" (Wai Care 2003). More recently, they are beginning to work more closely with Trees for Survival, another Auckland Council community initiative that works with reforestation and plantings in the Auckland region. The programme Wai Care runs has a heavy emphasis on getting communities participating in positive and constructive activities. Having more and more individuals, groups and communities involved increases their profile in the community attracting more volunteers and getting the healthy stream message across to a greater number of people. Wai Care groups are provided with a set of manuals with the intention that these will guide them in their monitoring and the management of their chosen streams. Manuals range from background information about the water resources and catchments of Auckland, to how to correctly collect data and interpret it using basic graphing and statistical techniques. Each manual is accompanied by a series or worksheet aimed to help with the establishment of an accurate monitoring programme and provide information and guidance on how to implement it.

Unlike the other two groups that this research focuses on, Wai Care does not align itself to one particular river or catchment. It operates throughout the greater Auckland Region across a number of waterways, areas and catchments. It is also not just one voluntary group but coordinates numerous individuals, groups and schools that take part in monitoring throughout the region. It has coordinators in South Auckland, Rodney, West Auckland, Central Auckland, Papakura, the North Shore as well as an overall project leader. The locations of the groups used in this research are demonstrated in Figure 2.5.

Wai Care encourages groups and individuals to establish their own monitoring programme with the aid of provided manuals and under the guidance of a coordinator. Targeted waterways range from drains to urban streams to semi rural waterways across several geographic locations, geologies and land uses.

Catchment Characteristics

Across the region, Auckland is dominated by volcanic substrates originating from the Auckland Volcanic Field (Institute of Geological and Nuclear Sciences 2001). Central Auckland is contains basalt lava and ash, along with mud, silt and sandstone. The sites further south – Mangare Scouts and the Gardens School – lie on more sedimentary type substrates of mudstone, sandstone and other alluvial deposits while still containing large proportions of volcanically derived geology including pumice, rhyolite and tephra (Institute of Geological and Nuclear Sciences 2001). In the north, where Save Our Sandspit and the Whanateau Harbour Care Group operate, the substrate is predominantly thick-bedded volcanic rich sand and siltstone (Institute of Geological and Nuclear Sciences 2001).

The highly urbanised environment of most of the Wai Care sites makes them considerably different to sites the SLLT and WRG monitor. While the SLLT does have sites located in the city limits of Christchurch, they are located on the outskirts of the city with reasonably low density development. Auckland's higher rainfall also makes the sites different with the continuing threat of contaminated runoff from motorways and developments flowing into these streams. The waterways monitored by Wai Care volunteers range from chanelised drains to urban streams to streams flowing through native bush.

Study Site Choice

Volunteers make their own choices about where to establish a monitoring site. While there is guidance from co-ordinators, the choice is much less structured than the WRG and SLLT sites and have often been selected due to concern about a particular activity or development prompting volunteers to become involved. However, as with the SLLT and WRG, the sites monitored all have easy public access or are on the land of the group that monitors them as is the case with the site at St Judes Scouts.

The choice of sites to compare was largely the result of the location of the Auckland Council monitoring sites. Not all Wai Care volunteers and sites could be included in this research or viewed first hand but those that were directly involved either through interviewing or data analysis are demonstrated on Figure 2.5a. Auckland Council sites were sought in close proximity to the Wai Care sites on Oakley Creek. These sites were chosen due to their proximity to a corresponding Auckland Council site, and there being consistent and reasonably continuous data for more than one site at this location. A close up view of the Oakley Creek sites and the Auckland council site can be found in Figure 2.5b. This yielded one site monitored by Auckland Council with three current and one past Wai Care monitoring sites located close to it.

a)

b)

Figure 2.5: Sites monitored for Wai Care by people who took part in this research; a) the sites visited as part of this study; b) enlarged map of the Oakley Creek (blue line on 'b') sites used in the volunteer and professional comparison (A – Save Our Sandspit Inc. (SOSSI) and Whangateau Harbour Care Group, B – Unitech Bridge and Friends of Oakley Creek; C – Kodesh Oakley Creek; D – St Judes Scouts Oakley Creek; E – Auckland Domain; F – Mangare Scout Group; G – The Gardens School; 1 – Auckland Council's Oakley Creek site).

2.2 Comparison of Volunteer Data to Professional Data

2.2.1 Methods Used by Volunteers

pH

The WRG, Wai Care and up until February 2010, the SLLT, all measure pH using indicator strips. Wai Care use Fisherbrand non-bleeding pH Indicator paper sticks while the other two groups use Neutralit® pH 5-10 strips. The methods for using these strips are the same. The strip is submerged in a water sample until the colours on the strips are no longer changing. These colours are then matched against a key on the box that contains the strips and gives a corresponding pH value to a sensitivity level of 0.5 pH units. After February 2010, the SLLT implemented the use of YSI EcoSense pH10 pH and Temperature Pens to measure pH. This is able to measure to a sensitivity of 0.01 pH units. This probe is placed in sample of water and left to stabilise before recording the result (Figure 2.6).

Figure 2.6: SLLT volnteers prepare to measure the pH at the Styx Mill Reserve site.

Water Temperature

All three groups measure water temperature by placing a thermometer in the waterway and leaving it to stabilise. The WRG and Wai Care use alcohol thermometers, as did the SLLT prior to February 2010. Following this date however, the SLLT, changed to using the YSI EcoSense pH10 pH and Temperature Pen to gain a digital water temperature reading.

Clarity

Clarity is measured by all groups using a SHMAK 100 centimetre clarity tube (Figure 2.7). The tube is filled with water while taking care not to disturb any sediment from the bed as this may influence the results. In the tube is a black disc attached to a magnet which is held in place by another magnet on the outside of the tube. The tube is stoppered with a black bung while the other end is clear plastic. The black disc on the magnet is brought to the bottom of the tube with the clear plastic and also where the centimetre measurements start. A location for carrying out the measurement is chosen out of the direct sunlight but where it is not too dark. The tube is held horizontal at eye level by the person taking the reading and the magnet with the black disc is moved away from the reader towards the black stopper at the other end of the tube. When the black disc is no longer distinguishable from the black stopper at the end, moving the black disc ceases, and the point where the disc is in the tube is where the reading is taken. This is repeated three times using the same sample of water and an average of these three readings is taken.

Figure 2.7: SLLT volunteers measuring clarity using a clarity tube at Smacks Creek. The volunteer on the left is looking through the tube for the black disc which the volutneer on the right is moving down the tube.

Conductivity

The SLLT and the WRG also measure the electrical conductivity of their waterways. Both groups use a Waterproof TDScan WP3 Pocket Conductivity Tester manufactured by Eutech Instruments. The probe is placed in a water sample and the value given is recorded.

Dissolved Oxygen

Wai Care measure DO instead of conductivity. For this, volunteers use an AccuVac® DO High Range Test Kit. Each kit contains glass ampoules which contain reagents that react with the water to form a solution of a specific colour which is associated with a certain DO concentration. This ampoule is placed tip down into a plastic 'holder' and then this holder is placed in a beaker containing a sample of water from the stream. The ampoule is then pushed downwards until its tip breaks off and water is sucked into the ampoule. The ampoule and its holder are then removed from the beaker and a stopper is placed on the broken end of the ampoule before it is shaken for 30 seconds to mix well and then left for two minutes to allow the colour to develop. A control sample of 10 mls is required to determine the DO concentration. The control sample is placed in its appropriate place in the top right of the provided colour comparator with the ampoule placed to its left. The comparator is then held up to the light (Figure 2.8). The comparator has a coloured disc that is visible through the control sample. This disc is rotated until the colour through the control sample matches the colour in the ampoule. The concentration, in mg/L, corresponding to the colour is then taken as the DO concentration.

Figure 2.8: Wai Care volunteers measure DO by comparing the sample with a coloured wheel denoting different concentrations of DO. This site is at the Unitech Bridge.

Nitrate and Nitrite

Concentrations of nitrate and nitrite are determined using HACH Aquachek strips in a similar way to pH. These strips are submerged in a sample of water from the stream, removed and then left for a few minutes before comparing the colour on the strip to a key on the box they come in. This key indicates presence or absence in the sample.

Phosphate

Phosphate concentration is established using an Aquaspex Microtest Phosphate-P kit. Using this kit, two five millilitre samples of the stream water are taken. One of the samples serves as a control and to the other seven drops are added of ‘Reagent A’ and one drop of ‘Reagent B.’ This sample is then thoroughly mixed before being left for five minutes to allow the reaction to occur and the colour to develop. Following this, the control and reagent samples are placed side by side on a key with the control sample sitting on the colours of the key. The two samples are then moved up or down the key with the colours being assessed through the control sample. When the colour of the reagent sample most closely resembles a colour on the key, the corresponding value in mg/L is considered to be the phosphate concentration of the sample.

Other monitoring

Volunteers also make notes on other aspects of the environment including riparian vegetation, land use, macrophytes, and stream substrate. Variables differ between the groups. The SLLT use these main aspects of the environment while the WRG record more in depth information related to the agricultural use of the land such as any upstream cattle crossings or harvesting of plantation forestry. Wai Care also make notes on smell and appearance of their targeted waterway. The WRG and Wai Care also measure other aspects such as flow velocity and invertebrate scores (Figure 2.9) however as these aspects are not part of this research, their methods will not be elaborated on.

Figure 2.9: Scouts analyse invertebrate samples under the guidance of a Wai Care volunteer.

2.2.2 Methods used by Professionals

Christchurch City Council

Temperature is the only parameter measured in the field by the CCC. Water samples are taken and stored appropriately in order to measure pH, conductivity and turbidity. These samples are then analysed by the Christchurch City Council Water and Waste Laboratory. This laboratory is accredited by International Accreditation New Zealand (IANZ) and carries out its analyses according to Water Information New Zealand (WINZ) methods.

Environment Canterbury

As with the CCC, ECan use a mixture of field and lab based methods. Temperature is measured in the field using a YSI probe. The other variables are measured from water samples taken from the appropriate site in the Environment Canterbury Laboratory using methods in accordance with the American Public Health Association (APHA). Conductivity is measured in accordance with APHA 2510 B, pH with APHA 4500-H B, and turbidity with APHA 2130 B. Further details can be found at http://www.standardmethods.org/.

Nelson City Council

Conductivity, pH, water temperature and turbidity are all measured in the field. A Sonde YSI WQS 650 is used to measure conductivity, pH and water temperature and a Hach 2100 Turbidity Meter is used to measure turbidity.

Auckland Council

Auckland Council also use a combination of field and laboratory measurements for their water quality data. Temperature, conductivity and DO are measured in the field. Nitrogen and phosphorus, turbidity, and pH are all measured in a laboratory from samples taken from targeted waterways. Auckland Council use Watercare Services Laboratory for their laboratory analysis.

2.2.3 Date ranges

The SLLT provided their complete data set of all recorded data between March 2004 and November 2011. The data set provides an almost continuous record of monitoring throughout this time period with the exception of February to August 2011. This period followed a major earthquake in February 2011 which resulted in raw sweage being discharged into various rivers around Christchurch and bank slumping, especially in the lower reaches of the Styx River. Because of this, it was deemed too unsafe to monitor during this period of time. The data set received spanned almost seven years, however there were some mistakes in the data resulting in > 50 data points being excluded for the purposes of this study.

The WRG had two main time periods of data to be analysed due to the cessation of monitoring at some of the sites. Data for the Teal River was extensive and spanned April 2000 through to August 2012. The sites at Lower Lud at Hira Store both covered 2000 to 2003. Hira Store is monitored regularly still however this data was not provided. The Kahikatea site had continuous data from

2000 until the end of 2005. As a result of these time periods, the results may not reflect the data currently being collected by the WRG.

The data from Wai Care also fell into two main periods of time. The most recent group covered April 2010 through until June 2012 and included the sites at Craddock Street and the Scout Den, while the other period covered between September 2002 and June 2004 and contained data generated from above the waterfall at the Unitech Bridge.

2.2.4 The SLLT Experience

Throughout the research, the SLLT have been engaged with on a larger scale than the other two groups. The researcher has become involved with the volunteer monitoring programme, taking part in the monthly monitoring in order to better understand and observe the techniques used. This was done for two main reasons. Firstly, members of the management team of the SLLT put forward the idea for this research. They wanted to know how effective and accurate their monitoring was, and also to identify and understand volunteers' motivations for their continued involvement and the benefits they gain. The second reason regards the representativeness of the SLLT. Wai Care is much larger with several groups operating independently of each other while the WRG is very small, now with only a handful of regular volunteers. The SLLT was considered to be the group most representative group due to its size, the range of volunteers taking part and the suitability of the monitoring programme for taking part in this research. As a result, their programme has been analysed more in depth compared to the other groups.

2.3 Statistical Analysis

2.3.1 Comparison of Professional and Volunteer Data

The WRG and Wai Care provided their data to accompany the SLLT data and the NCC, Auckland Council, ECan and CCC provided the professional counterparts. Some changes in the data set were required in order to make it able to be compared. The WRG and Wai Care data were cleaned in the same way as the SLLT data with missing values and obvious errors being eliminated. The volunteer CBM groups all record water clarity in the form of the distance an object is visible in a water sample, while the councils use turbidimeters to record turbidity in NTU units. In order to compare these data sets, they had to be standardised into the same units. To do this, clarity was measured using the same methods as the volunteer groups for several water samples. The turbidity (NTU) was also determined for each of these samples using a Turbiquant 1000IR turbidimeter. The turbidity was measured three times for each sample and a mean turbidity value was calculated. Plotting these two values against each other allowed for the generation of a calibration curve and for a formula to be computed in order to transform clarity values into turbidity.

All sites, both volunteer and professional were plotted on a map in order to determine which sites would be best to compare with each other. After pairs or groups of sites were chosen for comparison they were preliminarily plotted in a box and whisker plot.

2.3.2 Statistical Tests Used

The statistical package R 2.15.1 (R Core Team 2012) was also used to compare the professional and volunteer generated data sets. The pH, conductivity and water temperature data were transformed using power, root, inverse or inverse power transformations, in order to satisfy the assumptions of normality and were then statistically compared using an analysis of variance (ANOVA) to a significance value of 0.05. An ANOVA is a statistical model that is used to analyse the difference between the means of two or more groups (Zar 2010). An ANOVA generates an F-value and a p-value used to determine if the analysis results in a significant result or not. Larger F-values indicate a more significant result, while smaller p-values indicate a more significant result. If an ANOVA yielded a p-values of ≤ 0.05, the result was considered significant. The same level of significance for the p-value was used on all other statistical tests.

The turbidity data however, was analysed using a Kruskal-Wallis non parametric test. A Kruskal-Wallis test is often referred to as an analysis of variance by ranks (Zar 2010), and is employed if the assumptions of normality cannot be satisfied. This test was chosen due to the inability to transform the data so the error values resembled a normal distribution, therefore violating the assumptions of normality. As with a conventional ANOVA, a Kruskal-Wallis test returns a χ-value and a p-value that determine the significance of the test. As clarity measurements have a maximum of 100 cm due to the finite length of a clarity tube, there was a heavy bias towards this value in the data and therefore also once it has been transformed into turbidity values. Extrapolating these 100 cm values was considered, however, eventually it was decided this could not be done accurately due to the high number of unknown variables that may affect the reading. For one monitoring occasion, the actual clarity may be only a few centimetres more than the tube while on another occasion the actual value may be significantly longer.

One comparison of the SLLT data compared four sites – two SLLT, one CCC site and one ECan site, the only site ECan monitors in the Styx catchment. In this case, a Tukey's honest significant difference (Tukey HSD) test was able to be carried out in order to determine which sites differed from each other, to accompany the ANOVA results which just demonstrate if one or more of the sites are different from each other. Tukey HSD test also return a p-value revealing if there is a significant difference between any pairs of sites. As this test requires three or more sites to compare, it could not be carried out on the paired comparisons.

2.3.3 Further Analysis of the SLLT Data

The SLLT data was analysed more than that of the other two groups. The analysis aimed to determine the factors affecting the water quality, and if the water quality had changed over time. The variables of pH, water temperature, clarity and conductivity were first plotted against time in order to visually assess any obvious trends in the data.

Analysis of the data was completed using R 2.15.1 (R Core Team 2012), with the raw data transformed if necessary to satisfy the assumptions of normality using power, root, inverse, or inverse root transformations. The data is of a repeated measures design, as the ten sites are repeatedly sampled over time and as the sites are all in one catchment, so they could not be considered to be independent from each other. However, a repeated measures ANOVA was unable to be used as the eight possible predictors did not leave enough degrees of freedom (DF) to allow for the use of interactions in the model. Inputting more than one interaction into the formula resulted in no results being given for the 'among' sites ANOVA table as there was insufficient DF to allow for any calculations to be made.

In order to maintain the repeated measures design without the constraints of DF, a liner mixed effects (LME) model was used as a way to analyse any trends that may be present in the SLLT data set. This was completed in R using the 'lme4' package developed by Bates et al. (2004). Linear mixed effect models allow variables included in the research to be specified as either fixed or random. Fixed effects are variables where the levels of each variable represent every possible level of that variable, while random effects contain levels that may only be part of the entire population of levels (Bonate 2011). In this design, 'site' was considered to be a random variable as they represented only ten possible sampling locations out of an almost endless number of locations. Incorporating random effects can be considered to be another way of including error terms in order to account for correlation among data within the same group (Pinheiro & Bates 2000). The other variables were fixed. LME's return an 'effect size' value and a p-value for each individual predictor variable in a model, as well as for any interactions included in the model. The p-values determine what variables, if any have a significant effect on the response variable.

Four LME models were generated using the water quality parameters of pH, conductivity, water temperature and clarity as the responses, with the results of each indicating if any of the predictor variables – date, time, rainfall and distance from the sea – or the water quality parameters affected the response. Minimal models were used to start with, including no interaction terms. These terms were added afterwards and the Akaike Information Criterion (AIC) was used to determine the best model. The AIC is a measure of goodness of fit for a statistical model, the smaller the AIC value, the better fit of the model (Crawley 2007) therefore is was the model with the lowest AIC value that was used to determine significance.

2.3.4 Validation of the SLLT Techniques

The accuracy and consistency of the equipment available to the SLLT was investigated. Calibrated equipment from the Waterways Centre for Freshwater Management at the University of Canterbury was used to validate the pH and conductivity measurements generated by the CBM groups. To do this, a sample of water was taken from the Styx River and readings were taken using both calibrated and non-calibrated pH meters used by the SLLT, and the pH strips they used prior to February 2010. The same sample was then measured using a Radiometer MeterLab PHM201 Portable pH meter available from the Waterways Centre. Conductivity was measured with one of the SLLT's conductivity meters and also with a HACH HQ40d multimeter from the Waterways Centre. This process was repeated at a number of different locations on the Styx River, its tributaries and other waterways around Christchurch. The two data sets were then statistically compared using analysis of variance (ANOVA) analysis using R 2.15.1 (R Core Team 2012).

2.4 The Survey

2.4.1 Development

A survey was chosen as the main method of gaining information from, and about, the volunteers as it is particularly useful for obtaining people's attitudes and opinions about a specific topic (McLafferty 2003). This method is particularly helpful for gaining information about environmental opinions as they can vary significantly from person to person. Development of the survey began with some basic points about the sort of information that would be required. It was decided that there would be questions under four main sections: 1) Background information – including age, sex, and occupation; 2) Information about involvement in their specific CBM group; 3) Knowledge of the programme they are involved in; and 4) Knowledge about environmental issues.

From these four main topics, 17 informative questions were developed along with three basic questions in order to gather some background information. During the planning of the survey, it was decided that only open questions would be used, except for the three background questions. Open questions allow the respondent to freely decide the detail, length and form of their answer (Moser & Kalton 2004, Rea & Parker 2005). Closed, or pre-coded questions, give a limited number of responses and it is up to the subject to decide which one is most relevant to them. These questions, while useful for gaining basic information, do not allow for the same amount of depth as open questions and as the answers are limited to a specific set of responses, they allow for easy comparison between respondents (Rea & Parker 2005). Open ended questions are more likely to result in "don't know" answers that are of no use to the researcher (Krosnick & Presser 2010), however, this can be remedied by offering pre-coded answers with an "other" option and room for quantification. Despite this, it was decided that the volunteers who are involved, are so of their own choice, and therefore are likely to have an opinion or response to the questions that require them and the risk of receiving a "don't know" response would be minimal. Often, responses to open ended questions can be ideas or opinions the researcher would never have come up with on their own, but are nonetheless relevant and informative answers that may be unique to individual respondents and would not have been accurately represented in a pre-coded answer.

Consultation was carried out with Professor Eric Pawson from the Geography Department at the University of Canterbury in order to fine tune the question wording and order. Care was taken to use simple language and avoid technical terms the volunteers may not know and to ensure none of the wording was ambiguous. Following consultation, the order was altered slightly to ensure one question flowed naturally onto the next and some of the wording was fine tuned. A 'pilot' or 'pre-test' was then carried out on a small sample of friends and family to make sure the questions would yield appropriate answers. Pilot testing is an important part of survey development as it determines if the questions are easy to understand and answer, if the instructions are able to be followed without issue, if it is able to be completed in a reasonable amount of time, and that each question will generate an answer that will eventually be able to be analysed within a data set (McLafferty 2003, Rea & Parker 2005). These answers and any suggestions made were considered and the survey was altered slightly before being finalised.

The final survey is included in Appendix 1

2.4.2 Survey Delivery

Several methods were considered for distributing this survey. Mailing out the survey to pre identified volunteers was considered initially. These would have been completed by volunteers in their own time and then mailed back in a provided envelope before a specified date. Mail out surveys would be completely anonymously as there would be no contact between the respondent and the researcher and therefore one aspect of bias may be eliminated as respondents are generally more likely to answer truthfully and not give the response they think they should give. However, unless there is an incentive to mail back a survey such as an opportunity to win something, there is little inducement to complete and return the survey. As a result of this, mail surveys often have a significantly lower response rate than more personal methods of conduction (Rea & Parker 2005). Using this method also does not allow for any questions to be explained if the respondent does not fully understand them, meaning they are more likely to leave a question blank or answer it "don't know." In the end it was decided not to use this method as the number of volunteers available to survey was already limited and could not afford to be limited any further by relying on respondents to complete and return the survey of their own accord.

Delivering the survey via a telephone interview was also considered. This method allows for questions to be explained and for the researcher to prompt deeper answers or receive clarification for any responses that seem ambiguous. Data would also be able to be received immediately. However, conducting phone interviews can be difficult owing to the fact a lot of people are not open to this form of interviews and if not expecting the call, may hang up prior to the purpose of the telephone call being stated. There is also the possibility of not reaching targeted respondents due to their not being home when contact is made. This method was also disregarded in favour of in-person interviews.

Despite the challenges the literature identifies for face-to-face interviews (Rea & Parker 2005) it was decided that this would be the most effective method for delivering the survey in this research. One of the main barriers identified for in-person interviews is the lack of willingness of respondents to participate. As all respondents were part of one of three volunteer CBM groups, they were all aware of the research being carried out and had agreed to take part prior to the survey being administered. The lack of anonymity was considered to be one of the major downsides to using this method, however steps have been taken to ensure no personal information is published. Utilising the in-person approach to delivering the survey allowed for any questions to be explained if the respondent was unsure and for the researcher to ask the respondent to clarify or build on certain answers as is the case with a telephone survey. However, in-person surveys were eventually chosen as they would allow the survey to be delivered while a volunteer was carrying out their water quality monitoring and therefore these methods and protocols could be observed at the same time. Travel was required in order to observe these methods and therefore it was decided the surveys could be conducted on the same occasion.

Employing the in-person method for delivering survey also allowed for more informal interview questioning outside of the structure of the survey. This enabled the purpose of the research to be delved into more thoroughly with the volunteers. Discussion on other topics they felt were of interest such as issues with voluntary work, freshwater and the environment were also possible during these interviews. These answers were recorded on an audio device and were analysed at a later time.

2.4.3 Ethics Approval

Once the survey has been finalised and the method of delivery selected, an application was made of April 4, 2012, to the University of Canterbury's Human Ethics Committee to seek approval for the use of a structured questionnaire and for the audio recording of conversations with the volunteer monitors. Clarification and further information was sought by the Committee on April 16, 2012. Due to Operation Patiki being based out of a marae, Maori consultation was required, and undertaken with Dr Lindsey MacDonald from the School of Social and Political Sciences at the University of Canterbury. Following the conclusion of this, approval was awarded form the Ethics Committee on April 30, 2012, and the next stage of the research could commence.

2.4.4 Conducting the Survey

Contact was made with one member each from Wai Care and WRG in March 2012 who in turn liaised with members of their group to organise times and locations to meet to deliver the questionnaires and interviews. As a result of this, the research had been introduced to all volunteers via email or telephone by their volunteer coordinator, prior to meeting the author in person, and therefore they had a basic knowledge of what to expect with regards to the research.

Upon first meeting volunteers in July and August 2012, the research was introduced, and what was hoped to be achieved and how their involvement would benefit the research. An information sheet with contact details and further information on the research was also provided. Permission from each volunteer was sought before beginning the questionnaire or recording any comments. The questionnaire was then distributed to, and completed by, the volunteers.

The volunteers were then observed while they carried out the monitoring of their waterway. This was conducted in order to gauge how competent and comfortable they were using the equipment and to see if protocols were similar across the three CBM groups. During this time, the conversation was recorded in order to obtain expanded opinions of the programme they were involved in, and what they perceive they gain from being involved. During the conversation/informal interview, volunteers were prompted to expand on certain answers and experiences in order to fully understand the motivations behind being involved regularly.

Two of the groups of volunteers involved children taking part – Hira School with WRC, and a Scout group with Wai Care. As the ethics application did not include a request to work with children, no interviews or surveys with the children were conducted. In this case, only the teacher and parent in charge respectively, were interviewed as they were supervising the children carrying out the monitoring. They were relied on to give an indication of what the children liked and disliked about being involved, as well as how being involved had changed the way they look at the environment. Comments were recorded on an audio recording device to be analysed later.

2.4.5 Analysis of Survey Data

As the majority of the questions in the survey were open ended, the completed surveys were reviewed and coded prior to final analysis taking place. As open ended questions allow for a respondent to answer in any way they want, in order to analyse their responses they must be standardised in some way (Rea & Parker 2005, Cope 2010). There are several different types and methods for coding survey responses. These include content analysis, where the number of times a specific term or phrase is used is counted; manifest messages, which single out obvious messages, themes or points out of an answer; latent messages, which focus on the style of answer; and analytic codes, which incorporate both manifest and latent messages where a key theme is identified by the context and use of the theme identifies other messages (Weisberg et al. 1996, Cope 2010).

Manifest messages, identifying main points from each response, were used as the basis for coding responses to this survey. The coding was carried out in order to reduce the complexity of the data and arrange it into a logical structure to allow for analysis and exploration. The responses for a specific question were initially analysed to establish one or two main ideas that formed the basis of the response. These main ideas were then assigned a key word or phrase. For example, when volunteers were asked why they chose to become involved with their CBM the response "vested interest as the river provides our drinking water" was initially coded as having a 'direct impact on local life', "believe in the care of the environment" was coded as having 'concern for the environment', and "getting the kids involved to learn about the environment" was identified as 'providing education for children'. These initial codes were then further analysed to group similar responses into general categories. Involvement in the CBM programme due to the 'direct impact on local life' and 'concern for the environment' could be grouped together under the heading 'environmental concern' while 'providing education for children' fell into its own category. This same process was carried out for each question, resulting in between two and ten identified responses for each of the 17 questions.

For some questions, volunteers gave responses that identified more than one main point. In this case, their responses were coded into two or more of the relevant categories. For example, another respondent stated they were involved "to gain education about water quality and to assist with restoration of Auckland streams." In this case, their response fell into the 'environmental concern' category as well as 'education of self.' As a result of this, many of the questions had more coded responses than the number of respondents. Once the responses from each question had been assigned an appropriate code, the results were entered onto a spreadsheet and computed into percentages. These were then graphed using simple column graphs, plus or minus the standard error, to allow for easy identification of any trends and patterns in the results. Relationships were identified between each respondent's answers for different questions in order to ascertain if a certain response to one question led to a response to another question.

Responses to the informal questioning were analysed in a similar way to the formal survey, however, in this case, it was comments and quotes that were of interest rather than answers to specific questions. The audio from these conversations was evaluated at a later time, indentifying and noting down key points, settings for ideas and opinions the volunteers presented. These provided some background and reasoning for providing the answers they did, and helped distinguish issues and thoughts about the programmes they are involved in that were not brought up in the survey.

2.5 Quality Control and Study Limitations

Oddly, given that this project is largely about quality control and determining if volunteer data can be comparable to professional data, there is little that can be done for this study in the way of quality control. The professional bodies that provided the data to compare the volunteer data to have their own methods in place to ensure the quality of their data is maintained and not compromised. The volunteer data, while not inherently without quality control, is controlled to a much lesser extent as it is generated by volunteers and not professionals. However, protocols are in place and the same methods are followed on each monitoring occasion and therefore the quality of the data should be consistent over time.

There were, however, some occasions where data needed to be filtered before it could be analysed. In all data sets there were values that were suspect (for example pH values of 75 and clarity values that exceeded the 100 cm tube length). There were also several occasions where monitoring data for one month had been entered more than once. Fifty data points were removed from the SLLT data set as the same data had been entered two or three times and were therefore redundant. Other monitoring occasions were excluded due to missing data such as dates and times of monitoring. This resulted in a final SLLT data set for analysis with n=675. The WRG and Wai Care data also required data points to be removed for the same reasons.

All three groups also collect macroinvertebrate data. This data was not included in the research. The SLLT recently commissioned a study of their macroinvertebrate data (Suren 2012). As this research was instigated by member of the SLLT, further analysis of this data would have been redundant. Also the SLLT's methods for macroinvertebrate assessment are different from Wai Care and the WRG which would have made comparison of the groups difficult.

There were also several limitations that were not expected when the research was begun. The main one was the small number of volunteer groups monitoring water quality in New Zealand. Due to the fact the groups needed to be monitoring on a regular basis, there were only four groups available to work with, however only three of them were able to be used for previously mentioned reasons. Even if groups such as farming groups that periodically carry out monitoring following a fencing off or rehabilitation project were included, there would have still been very few groups to work with. As a result of this, only 18 people were able to be included in the survey research and therefore the results presented here may be an incomplete snapshot of the volunteer monitoring groups. However, despite the small number of groups and individuals, they span a broad range of geographic locations, ages and socio-economic groups, and therefore are considered to be representative.

The other limitations have to do with the data available to analyse and where this data was collected. As the research was reliant on data being collected by others, there have been gaps in the data that were unavoidable. For example, the lack of monitoring following the major earthquake in Christchurch in February 2011 means there was no opportunity to see any earthquake-related changes that may have been picked up in the volunteer data. The incomplete data does make it difficult to compare to professional data sets that were complete. There was also the limitation of the number and placement of sites monitoring takes place at. Not all sites from the professional and volunteer groups were located close to each other. As a result, some of the comparisons include sites that may be several kilometres from each other but were still much closer than other sites. Therefore, there will be variation in the data that is unable to be accounted for in this analysis, due to changes in the catchments, and between the sites, that is unable to be quantified.

3 Results

3.1 Comparisons of Volunteer and Professional Data

3.1.1 Styx Living Laboratory Trust Data (SLLT)

Following appropriate transformation the data sets generated by the volunteer groups were graphically and statistically compared to data produced by professionals from city and regional councils. The professional data sets encompassed the same catchments, although not always the exact same sites, and the same time periods as the volunteer data. The results are presented on box plots. The upper and lower boundaries of the box denote the lower (25th) and upper (75th) quartiles with the thick line in these boxes representing the median value. The distance between the upper and lower boundaries is the inter-quartile range (IQR). The fences are calculated using the equation $1.5 \times IQR$, with the result being added to, or subtracted from the upper or lower quartiles respectively. Outliers are indicated by circles outside the fence limits. Refer to Figure 2.2 for all site locations.

Head of the catchment

The first set of sites to be compared in the Styx catchment, are situated on Smacks Creek, near the head of the catchment (Fig 3.1). There are obvious differences between the volunteer and professional data for pH and turbidity. ANOVA determined the there was a significant difference between the professional and volunteer pH data sets ($F_{1, 103} = 213.78$, $p = <0.001$). Water temperature data could not be statistically differentiated ($F_{1, 103} = 0.033$, $p = 0.857$). The two data sets have almost the exact same mean temperature with the SLLT mean being 13.01 ± 0.20 °C compared to CCC's mean of 13.02 ± 0.20 °C. Turbidity was also found to be not significantly different ($F_{1, 103} = 1.632$, $p = 0.204$) despite the box plot suggesting there might be a difference. However, despite conductivity appearing to be similar on the box plot (Figure 3.1 c), statistics revealed the professional and volunteer data was highly significantly different ($F_{1, 103} = 13$, $p = <0.001$).

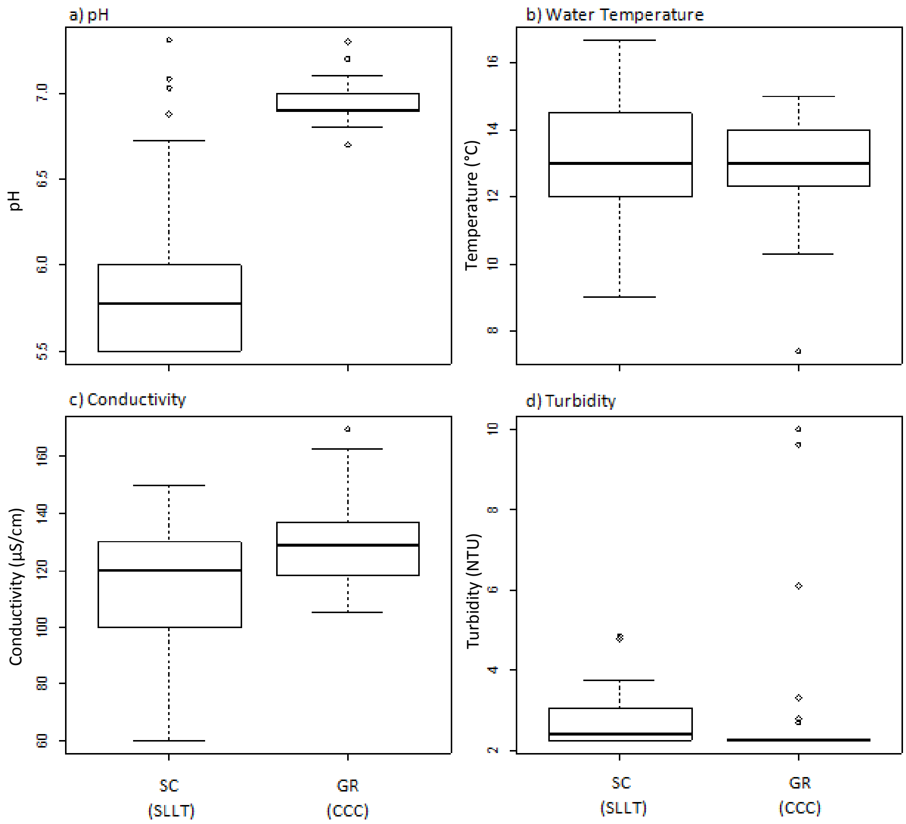


Figure 3.1: Comparison of the data sets generated by the SLLT and CCC for Smacks Creek (SC - Smacks Creek (n = 47); GR - Smacks at Gardiners Road (n = 58).

Redwood Springs (Upper-mid catchment)

For the next comparison data from the SLLT site Redwood Springs 1, and the CCC's Main North Road site were used (Figure 3.2). Again, the volunteer pH data appears to be very different to the professional data, while water temperature appears to be comparable. In this comparison however, there appeared to be obvious differences between professional and volunteer conductivity and turbidity data. Statistics supports these observations revealing that again, the pH data sets are very different ($F_{1, 106}$ = 666.4, p = <0.001). The volunteer's site at Redwood Springs yielded a median pH value of 6.5 ± 0.04, which was almost a whole pH unit less than the CCC's mean of 7.2 ± 0.02. Volunteer and professional conductivity data proved to be significantly different ($F_{1, 106}$ = 25.81, p = <0.001), as did the turbidity data ($F_{1, 106}$ = 18.982, p = <0.001). Water temperature was the only variable where no significant difference could be found between the volunteer and professional data ($F_{1, 107}$ = 0.033, p = 0.857).

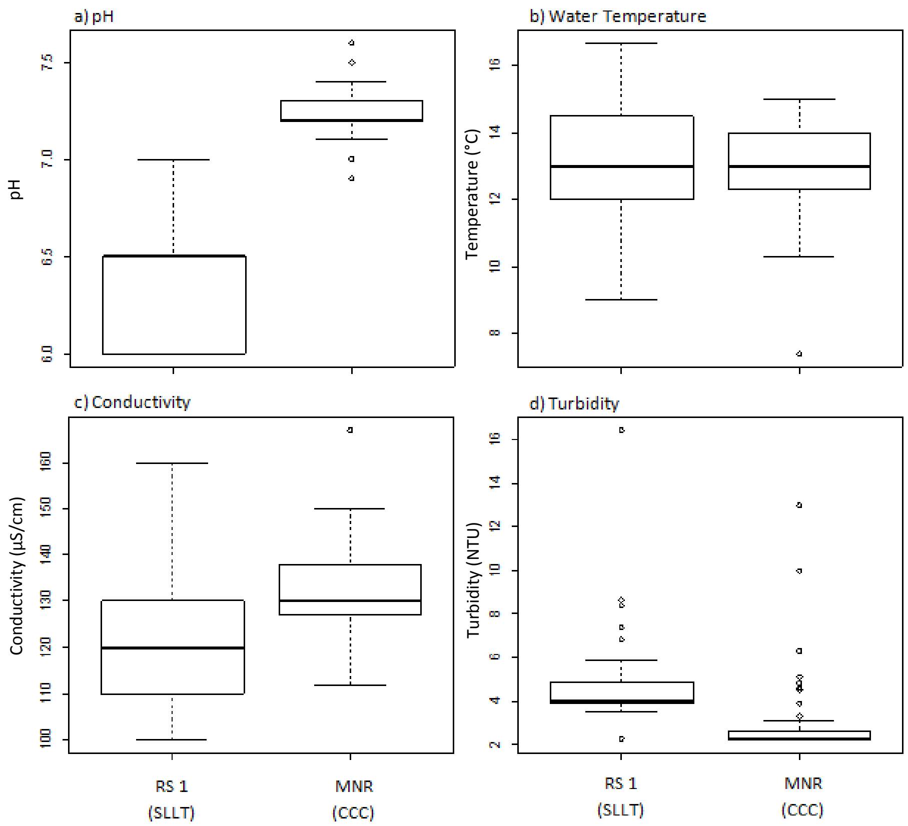


Figure 3.2: Comparison of data sets generated by the SLLT and CCC on the Styx River in Redwood (RS 1 - Redwood Springs 1 (n = 50); MNR - Main North Road (n = 58)).

Lower-mid catchment

This set of four data sets was treated slightly differently from the other comparisons for two reasons; 1) this was the only comparison where an ECan data set could be included, and 2) there were no SLLT sites close to the professional sites, and therefore two volunteer sites were used – one up and one downstream of the professional sites. The data for the two volunteer sites are generally much lower than for the two professional sites, for both pH and conductivity (Figure 3.3). There is less of a difference observed for water temperature and turbidity. ANOVA revealed the significant differences in pH ($F_{3, 107}$ = 135.99, p = <0.001) and conductivity ($F_{3, 107}$ = 14.17, p = <0.001), but no significant difference could be found between the professional and volunteer water temperature ($F_{3, 107}$ =2.48, p = 0.065) and turbidity data ($F_{3, 107}$ = 0.126, p = 0.944).

However, in this case, ANOVA is only able to determine if a difference exists between the four data sets used in this comparison, and is not able to tell which data sets differ from which. To do this, a Tukey HSD test was used. Tukey HSD tests only work if there are three or more categories of data to be compared, and therefore have not been of use for the other comparisons. Results from this test revealed both volunteer data sets differed significantly from both professional data sets. This result, accompanied by the ANOVA results demonstrates there is a significant difference between the volunteer and professional pH data. The same pattern was found for conductivity, once again demonstrating the difference between the volunteer and professional data.

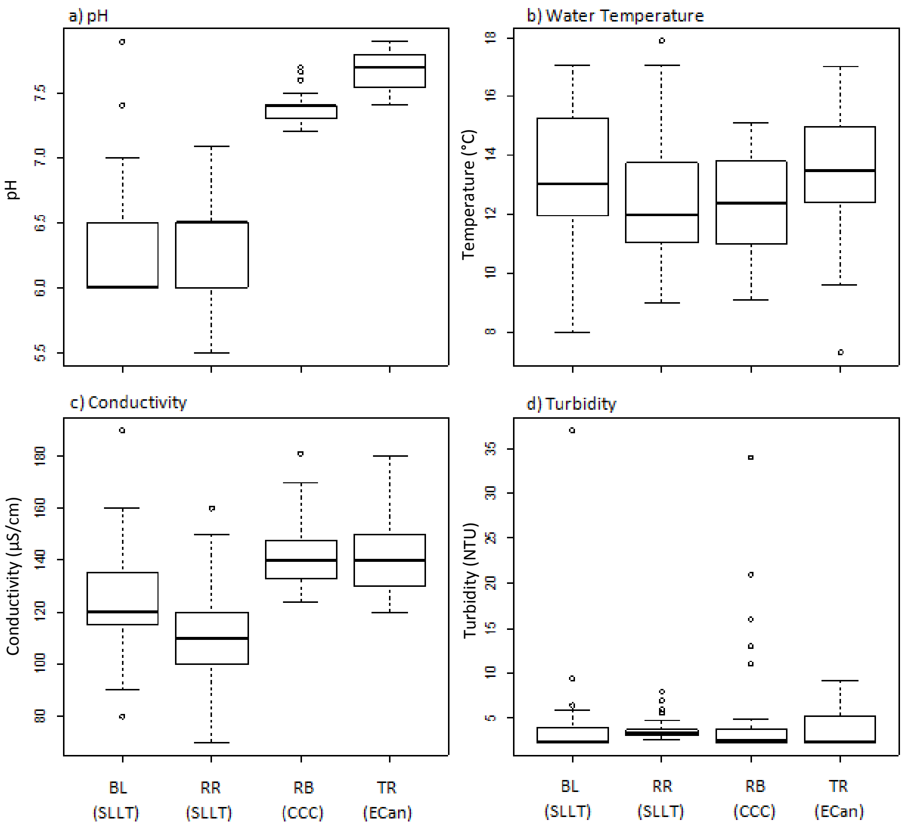


Figure 3.3: Comparison of SLLT, CCC and ECan data from sites on the Styx River; (BL – Brooklands (n = 28); RR - Radcliffe Road (n = 31); RB - Richards Bridge (n = 37); TR - Teapes Road (n = 15)).

Lower catchment

The final comparison for data in the Styx River catchment compares two data sets from very near the mouth of the Styx River influenced by estuarine conditions and even instances where the river appears to flow upstream due to the effects of the tides. Visual assessment of the box plots (Figure 3.4) suggests the volunteer and professional pH data is again very different, and conductivity is also able to be differentiated. There seems to be little difference between the turbidity data, while as with the other comparison, water temperature appears to again have comparable professional and volunteer data. Again, these differences are supported by statistics with ANOVA supporting the difference in the pH data ($F_{1, 80}$ =219.05, p = <0.001) and conductivity data ($F_{1, 80}$ = 38.283, p = <0.001). As with previous examples, the difference between the volunteer and professional data exceeds one pH unit, with the median values being 6 ± 0.06 and 7.4 ± 0.03 respectively. The water temperature data sets could not be statistically distinguished ($F_{1, 80}$ = 2.977, p = 0.088). Turbidity was analysed using a non-parametric Kruskal-Wallis test, as attempts to transform the data to satisfy the assumptions of normality proved unsuccessful. Results from this test demonstrated that the turbidity data sets were significantly different ($\chi = 14.829$, $p = <0.001$).

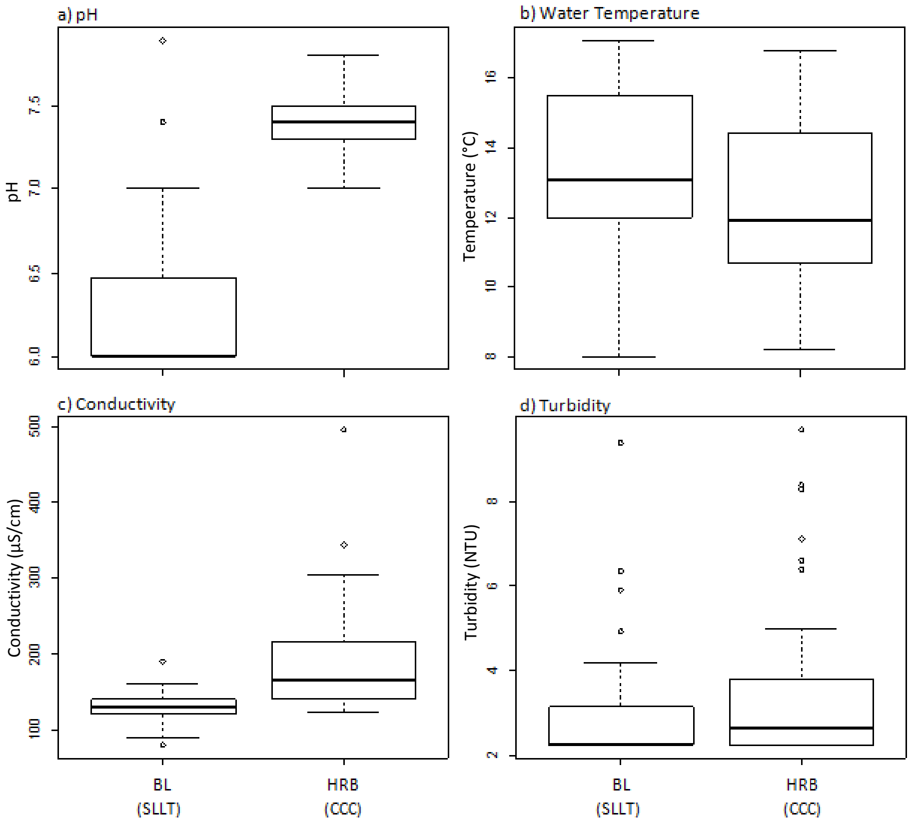


Figure 3.4: Comparison of data generated in the lower reaches of the Styx River at Brooklands; (BL – Brooklands (n = 24); HRB - Harbour Road Bridge (n = 26)).

Different pH monitoring equipment

In February 2010, the SLLT began using pH meters instead of the strips to determine the pH of the water. The data was divided according to the measuring method and compared to establish if the different methods had produced comparable results. The box plots of these comparisons (Figure 3.5) demonstrate obvious differences at two sites, Smacks Creek and Brooklands, but possible similarities at the other sites, Redwood Springs, and combined Radcliffe Road and Brooklands. These two sites were combined as both were used in the lower-mid catchment comparison. Statistical analysis of the data supports these patterns. ANOVA revealed a highly significant difference between the data measured using pH strips and the data generated with pH meters at Smacks Creek ($F_{1, 59} = 73.97$, $p = <0.001$), and at Brooklands ($F_{1, 68} = 32.994$, $p = <0.001$). Tests on the Redwood Springs data could find no significant difference between the strip and meter data ($F_{1, 62} = 1.434$, $p = 0.236$). The box plot for Radcliffe Road and Brooklands (Figure 3.5 d) suggests there may be a small difference in the measuring methods as the boxes span almost the same interval. Statistics shows there is indeed a significant difference between the strip and meter generated pH data ($F_{1, 139}$ = 9.304, p = 0.003). Further analysis of the different methods measuring the same water sample is presented later in Section 3.3.

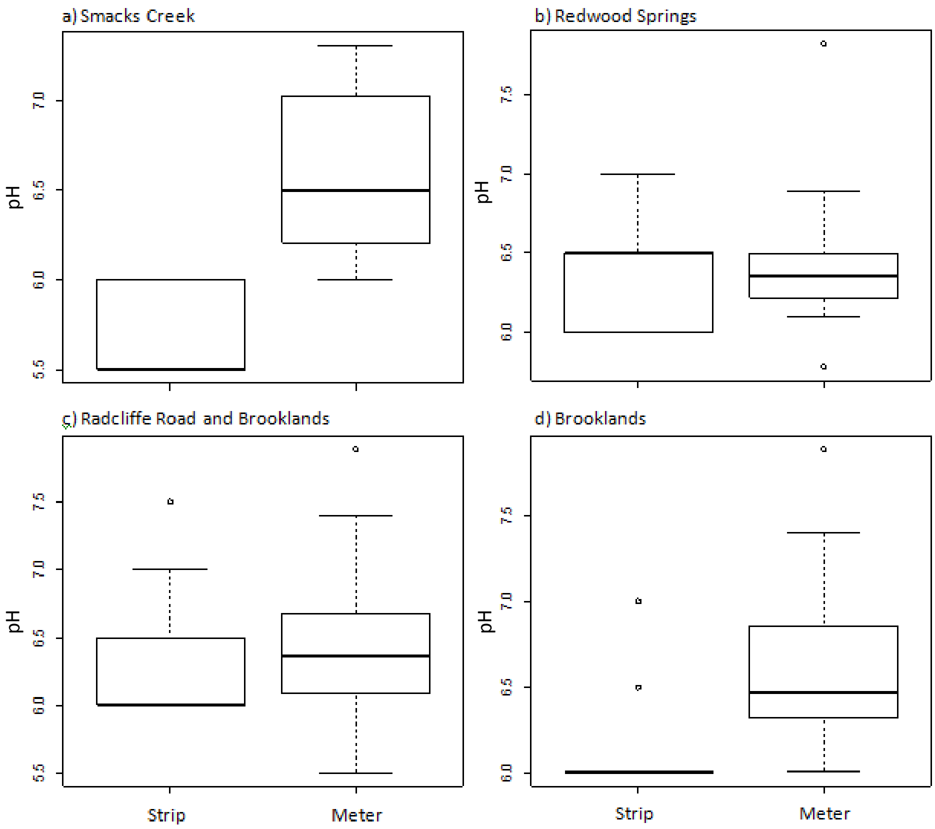


Figure 3.5: Comparison of data collected by the SLLT at four sites using their two different methods; the pH Strip data was collected prior to February 2010, and the pH Meter data collected after this date; (a) strip n = 51, meter n = 10; b) strip n = 48, meter n = 12; c) strip n = 116, meter n = 25; d) strip n = 58, meter n = 12).

3.1.2 Wakapuaka Rivercare Group Data (WRG)

Teal River

Comparisons for the WRG data were treated the same way as the SLLT's data as both groups monitor the same water quality variables. The first comparison for the WRG was for data collected on the Teal River, one of the major tributaries to the Wakapuaka River. This also presents the most extensive and continuous data set for the WRG. Visual assessment of the box plot comparison (Figure 3.6) suggest some level of difference between the volunteer and professional data for all four variables, however the difference between the water temperature data sets does not appear as obvious as for the other parameters. The volunteer and professional pH data were significantly different from each other ($F_{1, 92}$ = 350.4, p = <0.001). The difference between the median pH values was in excess of 1.5 pH units, the largest difference for all pH comparisons, with the volunteer data having a median value of 6.5 ± 0.06 compared to NCC's 8.3 ± 0.05. Conductivity ($F_{1, 92}$ = 45.3, p = <0.001) and turbidity ($F_{1, 92}$ 405.41, p = <0.001) were both found to have significantly different volunteer and professional data sets, confirming the visual differences in the box plots. A significant difference was also established for the professional and volunteer water temperature data ($F_{1, 92}$ = 4.406, p = 0.0385), the only site of all the comparisons where a significant difference existed for water temperature. There was a difference of almost 2° between the WRG and NCC sites where mean values were 10.68 ± 0.40 °C and 12.13 ± 0.50 °C respectively.

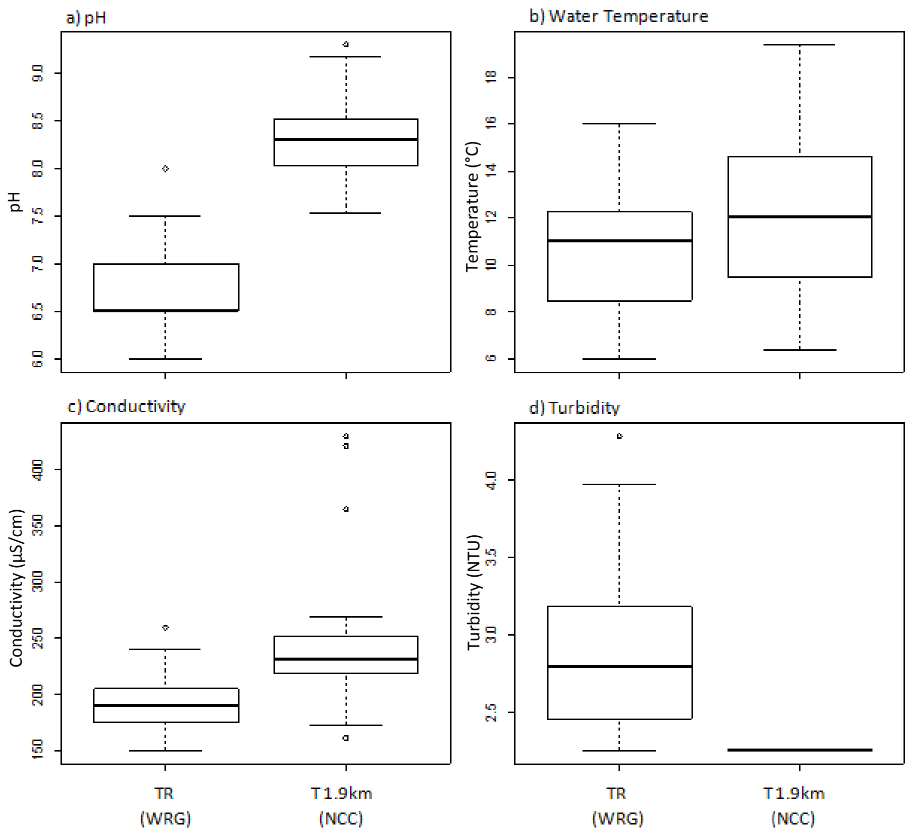


Figure 3.6: Comparisons of WRG and NCC data collected from the Teal River (TR - Teal River (n = 48); T1.9km - Teal at 1.9km (n = 48)).

Lower Lud

The WRG's site on the on the Lud River, another of the main tributaries for the Wakapuaka River, is an example of where the professional and volunteer sites are situated at almost the exact same location. Visual evaluation of the box plots (Figure 3.7) implies a substantial distinction between the volunteer and professional pH and conductivity data, but similar water temperature and turbidity data sets. Statistics support this observation with ANOVA yielding significant differences between the volunteer and professional data for pH ($F_{1, 28}$ = 102.4, p = <0.001) and conductivity ($F_{1, 28}$ = 36.95, p = <0.001). This site is another example of the professional data median of 7.8 ± 0.10 being over one pH unit greater than the volunteer data median of 6.5 ± 0.1 (Figure 3.7 a). No statistical difference could be detected in the turbidity (χ = 1.745, p = 0.187) or water temperature data ($F_{1, 28}$ = 0.021, p = 0.885). For this site, the mean water temperatures were essentially the same, with the WRG's mean being 12.56 ± 0.88 °C, compared to the NCC's mean of 12.57 ± 0.99 °C.

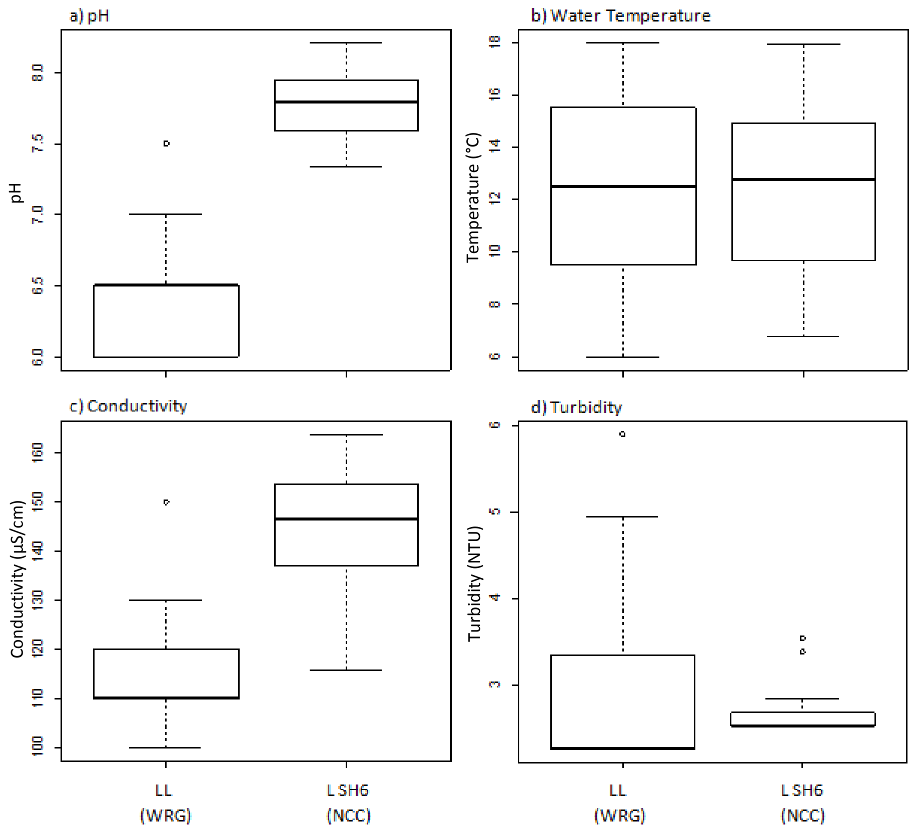


Figure 3.7: Comparisons of WRG and NCC data generated at the Lud River site (LL - Lower Lud (n = 18); L SH6 - Lud at State Highway 6 (n = 12)).

Wakapuaka at Hira

As with the Lower Lud site, the volunteer and professional monitoring sites at Hira are in almost the exact same location. This site is monitored for the WRG by pupils in Year Six from Hira School. The box plots present a similar picture to the previous comparisons. There is an obvious difference between the volunteer and professional data sets for pH, conductivity and turbidity, but similar water temperature data (Figure 3.8). Again, volunteer pH and conductivity data include readings consistently lower than their professionally collected counterparts and, statistical analysis confirms these visual assessments with a significant difference between the volunteer and professional data for pH ($F_{1, 26}$ = 42.7, p = <0.001), conductivity ($F_{1, 26}$ = 9.687, p = 0.005) and for turbidity (χ = 6.037, p

= 0.014). Again, no significant difference could be found in the water temperature data ($F_{1, 25}$ = 0.106, p = 0.747).

Lower Catchment

The final comparison for the Wakapuaka catchment involved another set of sites with a near complete data set, but their geographical proximity was not as close as for the Lud and Hira sites. These two sites are situated in the lower part of the catchment where the Wakapuaka River meanders through lowland agricultural land before it reaches the sea. The box plots for these sites (Figure 3.9) show the usual difference in the pH data sets. ANOVA again supported the visual difference in pH ($F_{1, 41}$ = 98.52, p = <0.001). The data from the volunteer site had a median pH value of 7 ± 0.09 and was significantly different to NCC's site at the bridge on Maori Pa Road which had a significantly higher median value of 8.2 ± 0.1 (Figure 3.9 a). The other three variables, conductivity, water temperature and turbidity, all appear to demonstrate similarity between the volunteer and professional data sets, but ANOVA resulted in a significant difference between the volunteer and professional conductivity data ($F_{1, 32}$ = 10.77, p = 0.002). However, the visual similarities for water temperature ($F_{1, 43}$ = 1.567, p = 0.217) and turbidity ($F_{1, 42}$ = 0.0194, p = 0.890) data showed no significant difference.

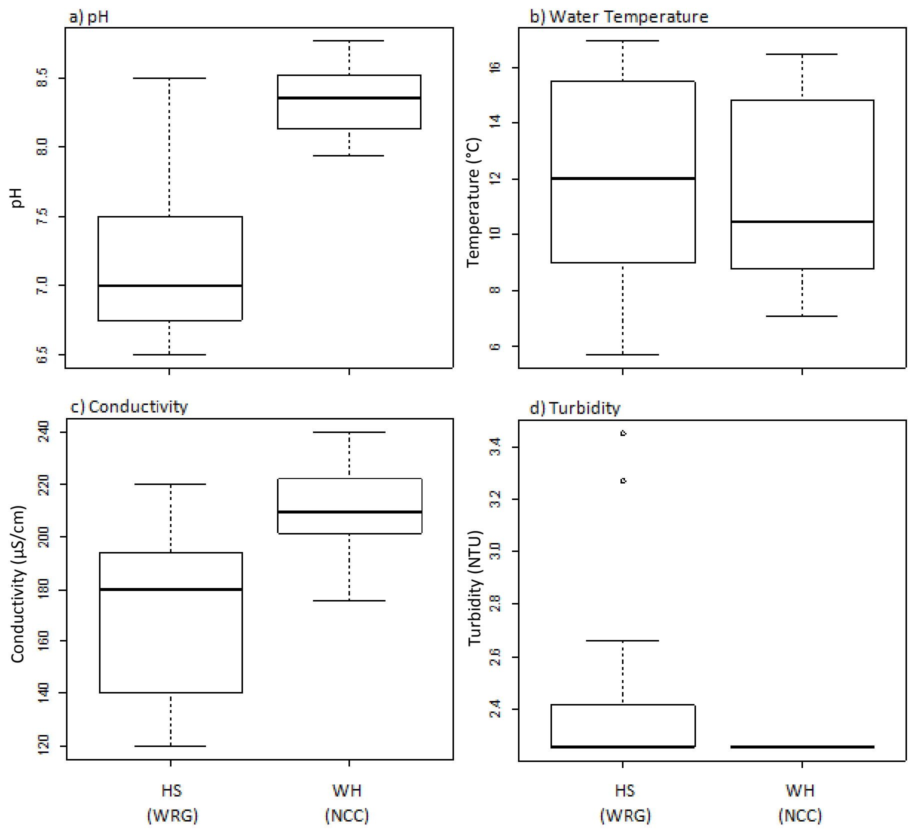


Figure 3.8: Comparisons of WRG and NCC data generated from the Wakapuaka river at Hira (HS - Hira Store (n = 16); WH - Wakapuaka at Hira (n = 12)).

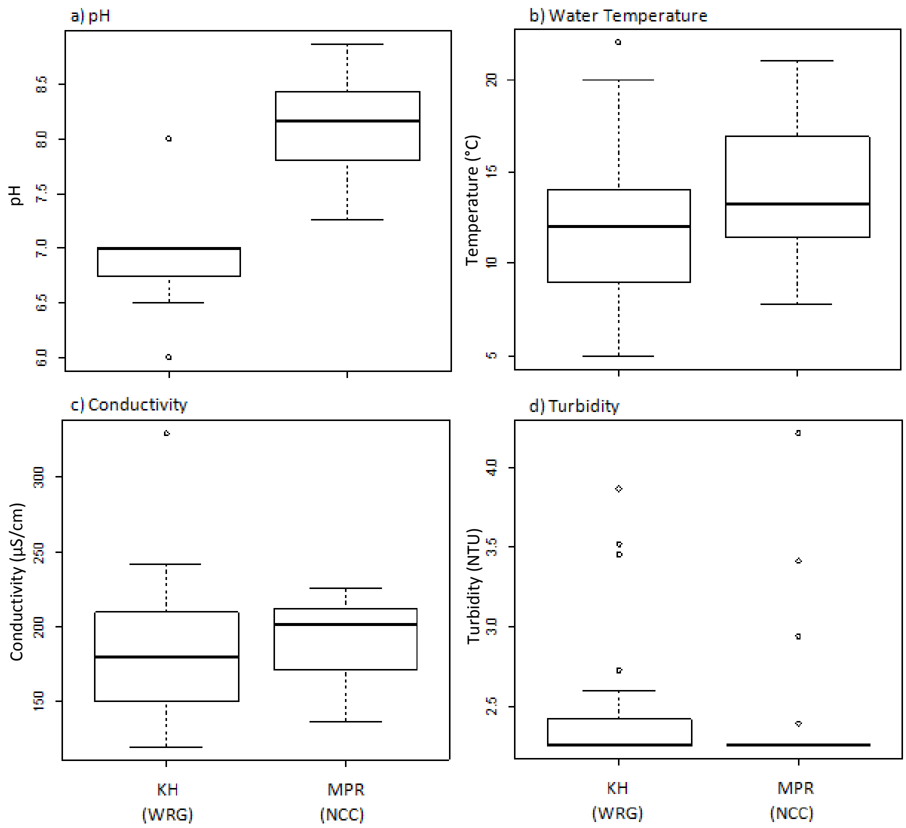


Figure 3.9: Comparisons of WRG and NCC data generated in the lower reaches of the Wakapuaka River (KH – Kahikatea (n = 25); MPR - Wakapuaka at Maori Pa Road (n = 20)).

3.1.3 Wai Care

Wai Care runs their programme differently to the SLLT and WRG in that they have a number of groups operating independently on a stream or site of their choice. The Wai Care comparisons compare data from number of groups operating on a two kilometre reach of Oakley Creek in Avondale, Auckland, with a data from site on Oakley Creek monitored by Auckland Council. As the data for the sites the volunteer groups monitor include two different time periods, data from these periods have been compared with Auckland Council data for Oakley Creek separately.

Older data (September 2002 - June 2004)

The first comparison of Wai Care and Auckland Council data compared the Auckland Council site on Oakley Creek to a Wai Care site located upstream, above a waterfall. Reviewing the box plots from this pair of sites (Figure 3.10) highlights a difference in the pH and DO data for the volunteer and professional data sets. A slight difference in the turbidity data sets is apparent, but water temperature appears to be very similar. The mean temperatures for each data set are virtually equal. The nitrate and nitrite – nitrogen (NO_x – N) measurements taken by Wai Care were added together in order to compare them directly to Auckland Councils data. Visual assessment of this box plot (Figure 3.11) suggests there is no difference between the two data sets.

Statistical analysis again confirms the visual assessment for pH ($F_{1, 93}$ = 189.59, p = <0.001) and DO ($F_{1, 92}$ = 25.373, p = <0.001). As with previous comparisons, the median pH for the volunteer data was much lower than the professional data (7 ± 0.05 and 7.6 ± 0.03 respectively). Water temperature did not exhibit any significant difference between the volunteer and professional data sets ($F_{1, 93}$ = 1.487, p = 0.226), and neither did turbidity (χ = 0.097, p = 0.756). No difference could be found between the volunteer and professional NO_x – N data ($F_{1, 79}$ = 1.425, p = 0.236).

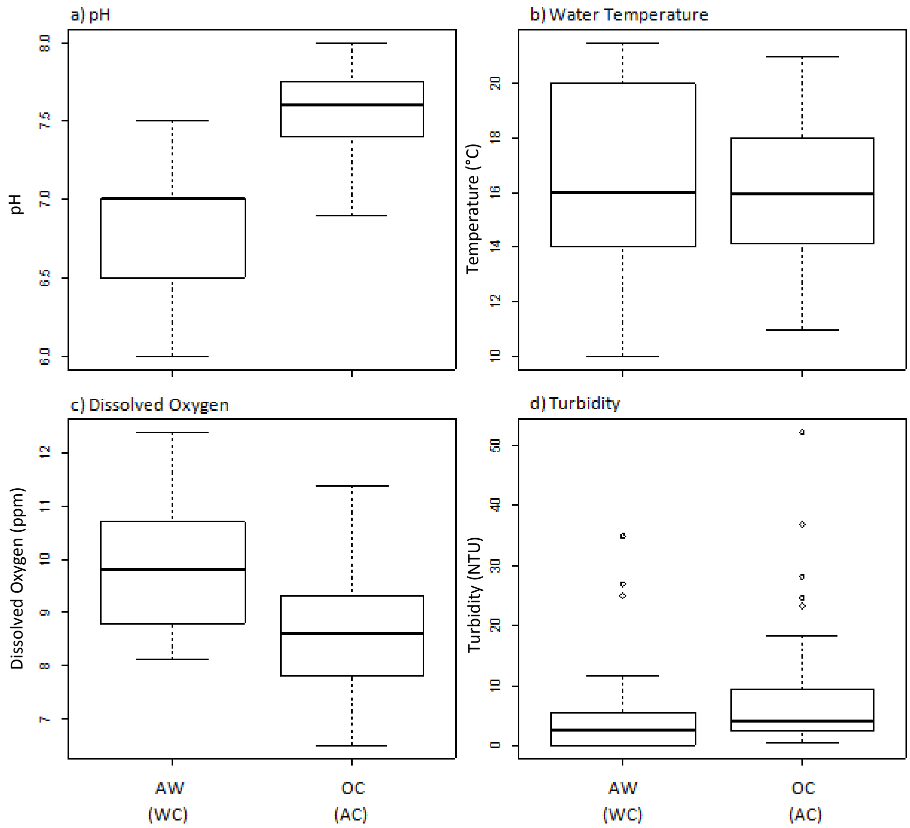


Figure 3.10: Comparison of Wai Care and Auckland Council Oakley Creek data 2002-2004 (AW – Oakley Creek Above Waterfall (n = 49); OC – Oakley Creek (n = 46).

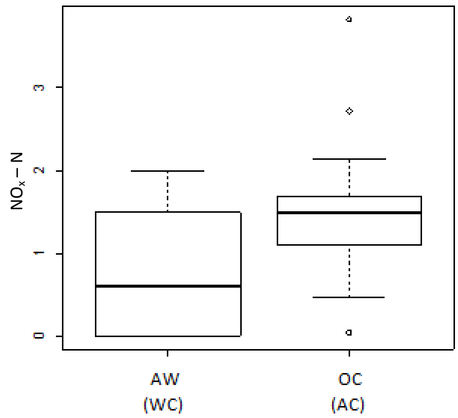


Figure 3.11: Comparison of Wai Care and Auckland Council NO_x – N for Oakley Creek 2002-2004 (AW – Oakley Creek Above Waterfall (n = 49; OC – Oakley Creek (n = 46).

New data (April 2010 - June 2012)

The second comparison of volunteer and professionally collected data uses the Auckland Council site on Oakley Creek and two volunteer sites located upstream at Craddock Street and the Scout Den, which are currently monitored on a regular basis by Wai Care volunteers. Reviewing the box plots (Figure 3.12) again demonstrates an obvious difference between the volunteer and professional pH data. However, other differences are harder to identify; with the professional data tending to give slightly higher concentrations of DO, and slightly lower turbidity readings. The professional water temperature data appeared to fall between each of the volunteer sights. Nitrate and nitrite (Figure 3.13) also show the professional data apparently falling between the two volunteer sets.

ANOVA confirms a significant difference in the pH between the data sets ($F_{2, 65}$ = 19.905, p = <0.001). Tukey HSD tests were required in order to establish which data sets were different from each other, and revealed that the Craddock Street and Scout Den sites were both significantly different from the site monitored by Auckland Council. Craddock Street and the Scout Den pH data were not different to each other. There was a significant difference detected for the water temperature data sets ($F_{2, 66}$ = 4.107, p = 0.021). However, Tukey HSD tests determined the volunteer data sets were only different to each other, and could not be statistically differentiated from the professional data. The slight difference in DO as assessed in the box plots was not confirmed by statistical tests as ANOVA detected no difference between any of the data sets ($F_{2, 66}$ = 1.030, p = 0.363). There was no also difference in the volunteer and professional turbidity data sets ($F_{2, 65}$ = 1.550, p = 0.220), but a difference was also detected in the nitrate and nitrite data comparison ($F_{2, 66}$ = 5.391, p = 0.007). Further analysis using Tukey HSD tests ascertained that on the Craddock Street data set differed significantly from the professional site while the Scout Den data did not.

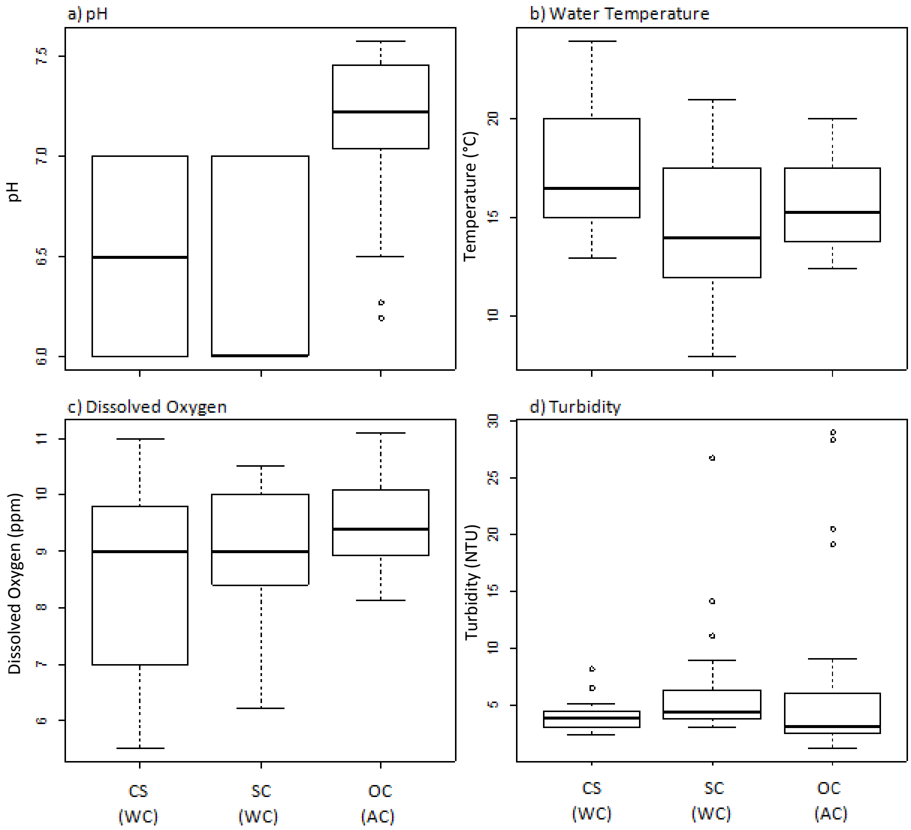


Figure 3.12: Comparison of Wai Care and Auckland Council Oakley Creek data 2010-2012 (CS – Craddock Street (n = 29); SC – Scout Den(n = 14); OC – Oakley Creek (n = 26)).

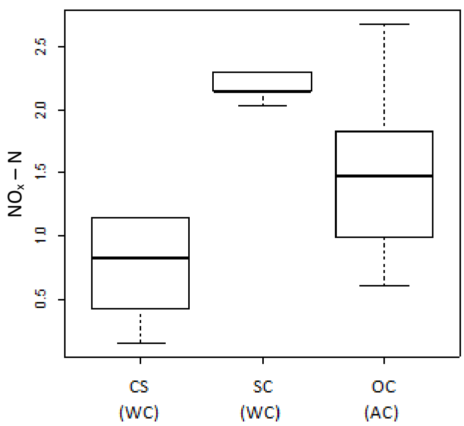


Figure 3.13: Comparison of Wai Care and Auckland Council NO_x – N for Oakley Creek 2010-2012 (CS – Craddock Street (n = 17); SC – Scout Den (n = 8); OC – Oakley Creek (n = 26)).

3.2 Analysis and Trends in the SLLT Data

As part of the higher level of engagement with the SLLT, their data was analysed further in order to determine any trends or issues that may be present in the data, and to provide volunteers with tangible results identifying (if any) changes in the water quality have occurred during the period of the monitoring programme.

3.2.1 Spatial Trends

Each site was statistically compared to each other using an ANOVA to determine if there were any differences among the sites, and Tukey Honest Significant Difference (Tukey HSD) tests were used to show which sites were different. Results from the ANOVA test revealed that pH ($F_{9, 665}$ = 20.584, p = <0.001), conductivity ($F_{9, 665}$ = 22.964, p = <0.001), water temperature ($F_{9, 665}$ = 6.728, p = <0.001), and water clarity ($F_{9, 665}$ = 15.764, p = <0.001) all had at least one site that was significantly different from other sites. Results from the Tukey HSD tests demonstrate which of the sites are different (Table 3.1). In the table, results from the Tukey HSD tests are expressed as p-values with significant results (≤ 0.05) indicated with an asterix. For example, in Table 3.1 a, Brooklands and Everglades Golf Course, pH data are significantly different from each other with a p-value of 0.027.

The pH values for Smacks Creek and Willowbank were both significantly different from almost every other site, except each other (Table 3.1 a). The site at Styx Mill was also significantly different from every site except Smacks Creek and Willowbank. Styx Mill is also located just downstream of the confluence of the Styx River and Smacks Creek, therefore this site will reflect the characteristics of Smacks Creek. The three sites at Redwood Springs exhibited no statistical differentiation from each other, which is to be expected from sites that are only one kilometre apart. Ouruhia Domain and Everglades Golf Course were also not different from each other.

Clarity exhibited similar patterns, though they were not as discernible as for pH (Table 3.1). Smacks Creek and Willowbank were again significantly different to almost every other site, but are similar to each other. However Styx Mill only differed significantly from four of the nine other sites. Radcliffe Road and Brooklands were also significantly different to almost half of the sites, possibly due to these sites having a wide, deep water body and with little obvious flow velocity. They are also the two sites lowest in the catchment, and therefore are affected by everything that has entered the catchment upstream. Conductivity also demonstrated the same basic patterns with Smacks Creek and Styx Mill being different to most of the other sites.

Unlike the other three variables, results from the Tukey HSD test for water temperature presented few patterns. One third of the comparisons revealed significant differences between sites, but this is generally to be expected due to differences such as flow, depth, riparian vegetation and substrate at these sites. The three Redwood Springs sites however did demonstrate a rudimentary pattern of dissimilarity to the other sites.

Table 3.1: Tukey HSD p-values derived from ANOVA comparing each site to all other sites. Sites are considered to be significantly different to each other if the p-value is less than 0.05. Significant results are indicated with an asterix (BL: Brooklands; EGC: Everglades Golf Course; OD: Ouruhia Domain; RR: Radcliffe Road; RS 1: Redwood Springs 1; RS 2: Redwood Springs 2; RS 3: Redwood Springs 3; SC: Smacks Creek; SM: Styx Mill Reserve; WB: Willowbank).

a) pH

	BL	EGC	OD	RR	RS 1	RS 2	RS 3	SC	SM	WB
BL		0.027 *	0.022 *	0.555	0.241	0.18	0.062	<0.001 *	0.349	<0.001 *
EGC			1	0.957	0.999	0.999	1	<0.001 *	<0.001 *	<0.001 *
OD				0.941	0.999	0.999	1	<0.001 *	<0.001 *	<0.001 *
RR					0.999	0.999	0.983	<0.001 *	<0.001 *	<0.001 *
RS 1						1	0.999	<0.001 *	<0.001 *	<0.001 *
RS 2							0.999	<0.001 *	<0.001 *	<0.001 *
RS 3								<0.001 *	<0.001 *	<0.001 *
SC									0.651	0.999
SM										0.313
WB										

b) Clarity

	BL	EGC	OD	RR	RS 1	RS 2	RS 3	SC	SM	WB
BL		0.074	0.264	0.974	<0.001 *	<0.001 *	<0.001 *	0.256	0.984	0.39
EGC			0.999	0.706	0.614	0.96	0.218	<0.001 *	0.668	<0.001 *
OD				0.95	0.276	0.34	0.06	<0.001 *	0.934	<0.001 *
RR					0.008 *	0.012 *	<0.001 *	0.009 *	1	0.018 *
RS 1						1	0.999	<0.001 *	0.007 *	<0.001 *
RS 2							0.999	<0.001 *	0.011 *	<0.001 *
RS 3								<0.001 *	<0.001 *	<0.001 *
SC									0.012 *	0.999
SM										0.024 *
WB										

c) Conductivity

	BL	EGC	OD	RR	RS 1	RS 2	RS 3	SC	SM	WB
BL		0.999	0.864	<0.001 *	0.009 *	0.065	<0.001 *	<0.001 *	<0.001 *	0.819
EGC			0.963	<0.001 *	0.002 *	0.021	<0.001 *	<0.001 *	<0.001 *	0.593
OD				<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *	0.04 *
RR					0.491	0.151	0.982	0.999	0.109	<0.001 *
RS 1						0.999	0.993	0.245	<0.001 *	0.529
RS 2							0.859	0.054 .	<0.001 *	0.897
RS 3								0.871	0.004 *	0.059
SC									0.354	<0.001 *
SM										<0.001 *
WB										

d) Water temperature

	BL	EGC	OD	RR	RS 1	RS 2	RS 3	SC	SM	WB
BL		0.97	0.999	0.15	<0.001 *	<0.001 *	<0.001 *	0.999	0.877	0.8
EGC			0.999	0.853	0.006 *	0.017 *	0.035 *	0.999	0.999	0.999
OD				0.375	<0.001 *	<0.001 *	0.003 *	1	0.987	0.967
RR					0.414	0.621	0.767	0.553	0.97	0.987
RS 1						0.999	0.999	<0.001 *	0.023 *	0.036 *
RS 2							1	0.004 *	0.058 *	0.084
RS 3								0.009 *	0.106	0.148
SC									0.997	0.991
SM										1
WB										

3.2.2 Temporal Trends

Diurnal trends

On a daily basis some water quality parameters can change through the day. As the SLLT have previously carried out monitoring of different sites at several different times during a single day, the possible diurnal variation in pH needed to be considered. Figure 3.14 demonstrates pH readings taken by the author, hourly between 7am and 7pm at the Redwood Springs 3 site on Sunday February 10, 2013. There is a difference of almost half a pH unit between the lowest measurement (7am) and the highest (2pm), and measurements can change rapidly as demonstrated by the increase between 11am and 12 noon.

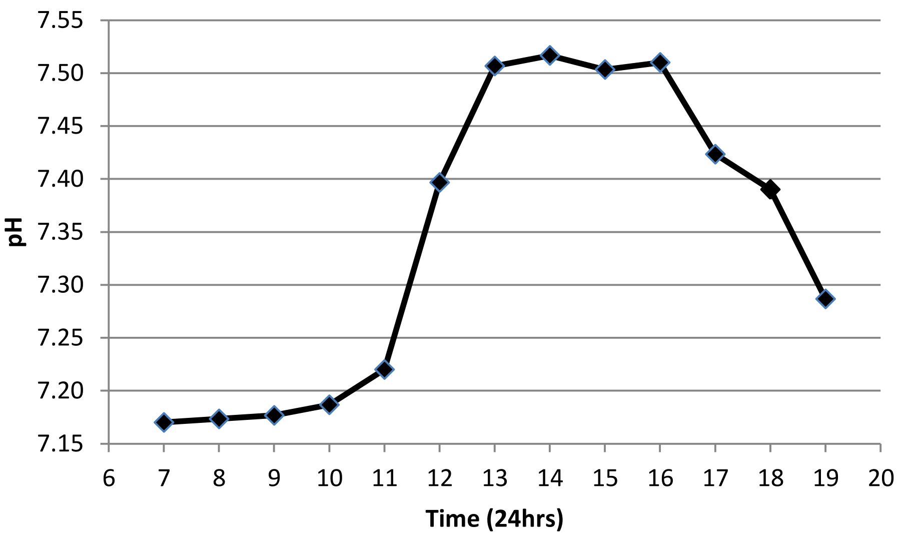


Figure 3.14: Changes in pH over time, measured between 7am and 7pm at Redwood Springs 3, Styx River

Seasonal trends

Each water quality parameter was graphed over time in order to visually assess any trends in the data. Figure 3.15 presents a selection of these graphs that are considered to be a representative sample of the graphs. Water temperature measurements at all sites demonstrate some degree of seasonal variability (Figure 3.15 a & b) with an annual sequence of peaks in December, January or February and lows in June or July. Some of the sites, especially Smacks Creek, Styx Mill Reserve, and the sites at Redwood Springs do not have seasonal peaks and troughs that are as well defined as the Brooklands, Radcliffe Road and Willowbank sites. None of the other variables demonstrate seasonal cycling as emphatically as water temperature, but there is some suggestion of a pattern for conductivity (Figure 3.15 g). Brooklands, Radcliffe Road and the three Redwood Springs site all show some form of seasonal peaks and troughs.

Longer term trends

The four main water quality variables routinely measured by SLLT volunteers over time were pH, conductivity, water clarity and water temperature (e.g. Figure 3.15). From visual analysis of the typical graphed raw data over time, there were some apparent trends; the main exception of this being the obvious seasonal cycling of water temperature as already mentioned. Another obvious pattern in the data was the upper limit of the clarity measurements. All three sites at Redwood Springs experienced a more subdued seasonal change since 2009, with much fewer obvious peaks and troughs in temperature, when compared to the previous years' data.

The three sites at Redwood Springs appear to have increasing pH values since the end of 2009 (Figure 3.15 c). The water clarity at Everglades Golf Course and the Ouruhia Domain also appears to have increased from around 60 cm to regularly being ≥ 100 cm for more recent monitoring (Figure 3.15 e).

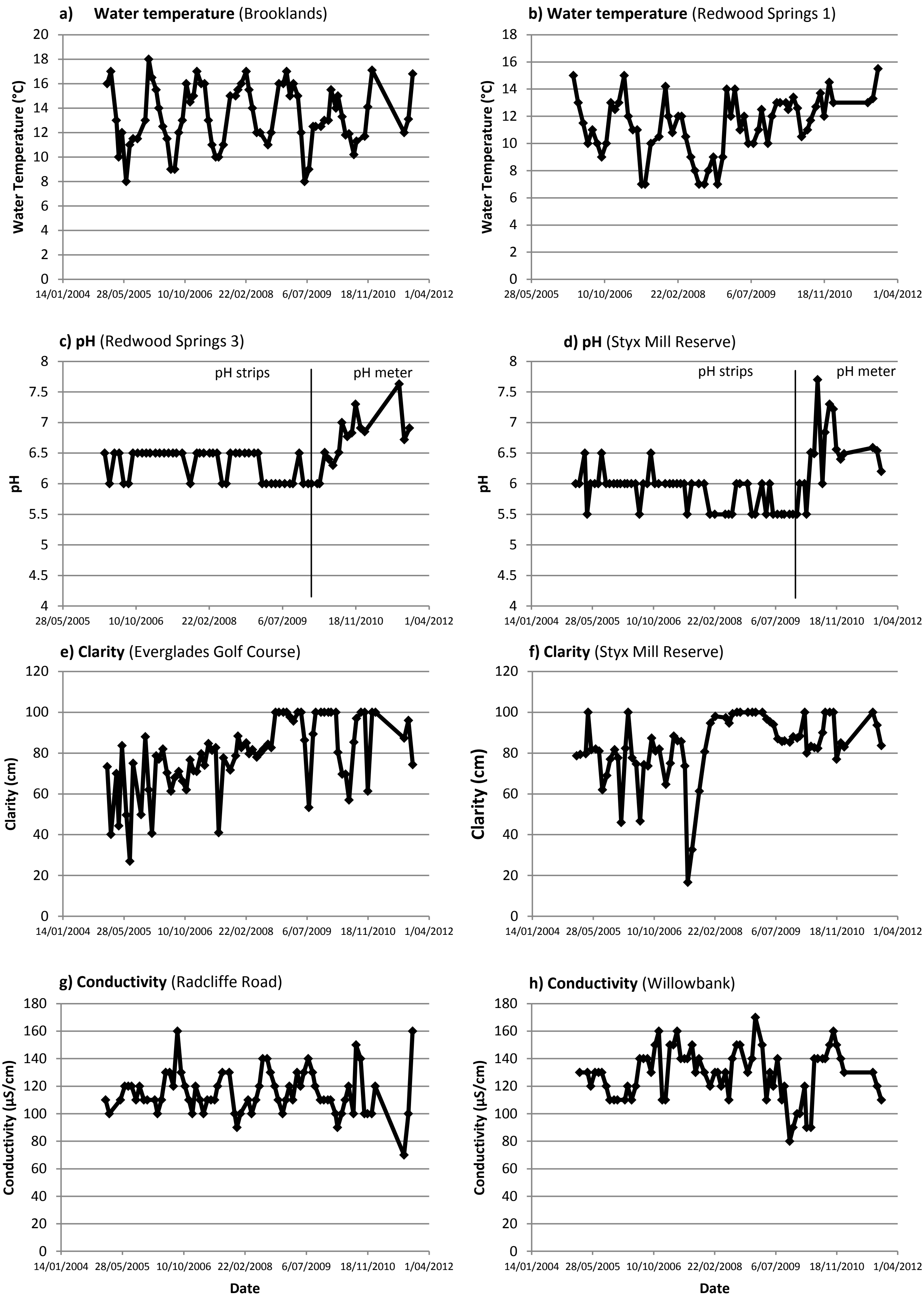


Figure 3.15: Variables for selected sites as a function of time.

3.2.3 Statistical trends

Linear mixed effects (LME) modelling was carried out on the data in order to determine if there were any trends and changes that were statistically significant over time, or if other variables affected the water quality. Full statistical results are presented in Appendix 2.

pH

Date, time of day, distance from the mouth, conductivity and clarity were all found to significantly affect the pH at each of the sites. However, they all had relatively small effect sizes. The largest effect size was the affect of conductivity on pH with a mean effect size value of -0.229. Date and time, and date and conductivity presented significant two way interactions where the effect of time and conductivity respectively, depended on the date. There were several significant three way interactions, however these had very small effect values while still being considered to be highly significant. All effect sizes were only very slightly positive or negative. Effects of this size have very little effect on the variable in question. There were no significant interactions of four variables or more.

Conductivity

As with pH, several of the variables were determined to have a significant influence on the conductivity measurements for the various sites. Date, time, distance from the mouth, water temperature and pH were all found to have significant effects on conductivity. Rainfall in the last 24 hours and clarity were the only single factors not to be significant. Conductivity also had several significant interactions. Date and time, date and pH, time and water temperature, and time and pH were all highly significant meaning the effect of the second variable depended on that of the first. The significant affect of date, does suggest there may be something to the suggested seasonal pattern identified from the graphs (Figure 3.15).

Water Temperature

The results of the LME model for water temperature also revealed that most of the single variables had a significant effect on the temperature of the water (date, time, distance from mouth, clarity, conductivity and pH). The variables that were significant however, were not as emphatic as with pH and conductivity as some of the p-values fell just below the specified significance level of 0.05. Again, pH is the only variable that has an effect value of any size (-83.728) with the values of the other variables, including interactions being very small. Dates coupled with distance from the mouth, pH and conductivity to provide significant two-way interactions where the significance of the latter depended on the effect over time. There was only one three-way interaction that was significant however, as with other interactions, it has an inconsequential effect size and therefore is likely to have very little importance. However, the significant affect of date supports pattern on the graphs (Figure 3.15) with the water temperature significantly changing depending on the time of year.

Clarity

Water clarity was the only one of the four responses that had three individual variables presenting non significant results (distance from mouth, water temperature and conductivity). Date and time were once again highly significant as they have been with the other three. Date and time were again prevalent in the two-way interactions. Date paired with time, and conductivity, and time paired with water temperature and conductivity to deliver significant interactions, however, as with the other interactions, these demonstrated a very low effect size. There were no significant three-way interactions. The suggested pattern of increasing clarity at some of the sites (e.g. Everglades Golf Course) do appear to be supported with statistics by a significant affect of date.

3.3 Validation of Volunteer Techniques

The SLLT technical monitoring equipment was compared to equipment used by the Waterways Centre for Freshwater Management at the University of Canterbury at 20 different sites around Christchurch. Each piece of equipment took measurements from the same samples of water in order to determine the accuracy of the equipment available for the volunteer groups (Figure 3.16). Both the calibrated and non-calibrated pH meters used by the SLLT measured pH values a little higher than the Waterways meter, but the calibrated meter was only very slightly different (Figure 3.16 a). The pH strips measured a pH to be much lower than the Waterways meter, with a difference of over one pH unit. The two conductivity meters measured similar values (Figure 3.16 b) but slightly higher than the Waterways meter.

Statistical analysis revealed there was at least one significant difference between the four different methods for measuring pH ($F_{3, 76}$ = 63.195, p = <0.001), so a Tukey HSD test was required to determine which methods were different. The only pair of methods shown not to be significantly different from each other was the Waterways Centre pH meter and the calibrated SLLT pH meter (p = 0.526). All other pairs of methods were significantly different to each other, with the pH strips used by the SLLT before February 2010 particularly different. Conductivity measurements was also compared (Figure 3.16b) but no significant difference found ($F_{1, 38} = 0.927$, $p = 0.342$).

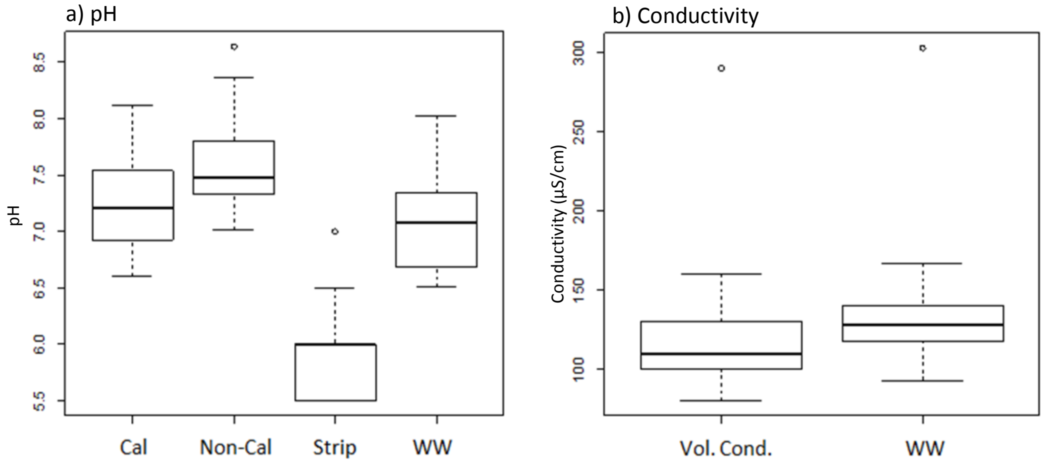


Figure 3.16: Comparison of volunteer measuring methods for pH and conductivity with professional equipment n = 20 (Cal – Calibrated volunteer pH meter; Non-Cal – Non-calibrated volunteer pH meter; Strip – volunteer pH strips; WW – meter from the Waterways Centre; Vol. Cond. – Volunteer conductivity meter).

3.4 Survey Results

3.4.1 Demographics

Eighteen members across three volunteer groups completed a survey to provide information about their involvement, reasons for being involved and knowledge of the programme, and also to collect some basic demographic information. Of these, 13 of those surveyed were female, and five were male, however the ratio of male to female volunteers differed with each group. The SLLT had the most females involved (83% of volunteers) while the WRG had the most males involved (40% of the volunteers). The most popular age group for the volunteers (Figure 3.17) was 61-70 years (28% of the volunteers). There was only one volunteer each to fall in the < 20 and > 71 years of age groups, and almost half the volunteers with Wai Care were < 30 years of age while 80% of the volunteers with the WRG were ≥ 51 years old. Occupations ranged from students (17%) to retired (17%) (Figure 3.18) with the most common occupation being work in a science related field (28%), and were generally in the specific field of environmental science. Teaching was also popular occupation at 17% of the volunteers.

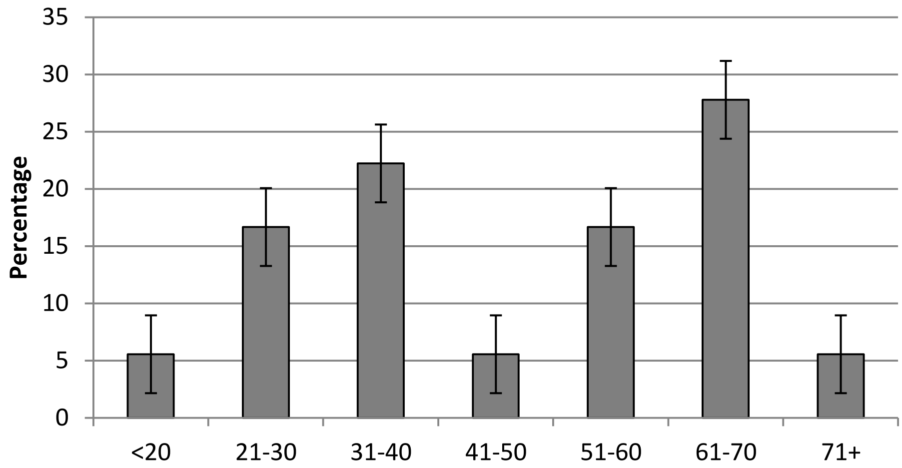


Figure 3.17: Age demographics across all volunteer groups; n = 18 (error bars ± standard error)

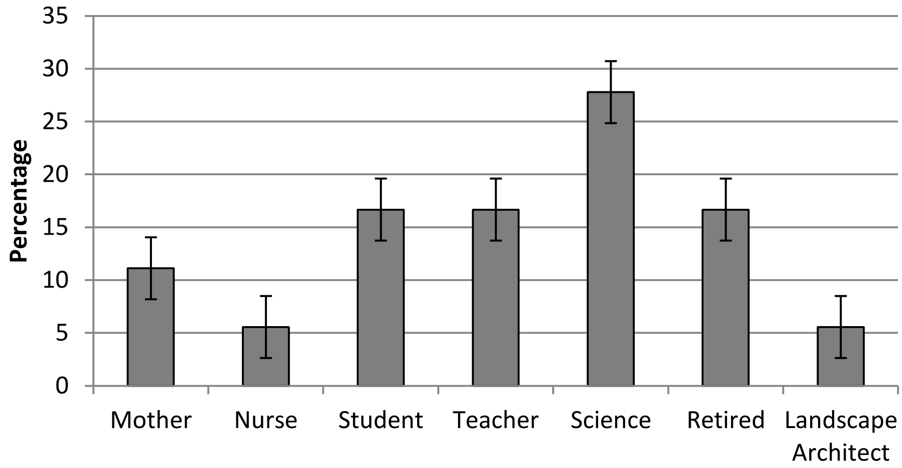


Figure 3.18: Volunteer occupations across all volunteer groups; n = 18 (error bars ± standard error).

3.4.2 Volunteer Involvement

Overall, volunteers had been members of their volunteer water quality monitoring group for an average of 3 years 7 months. However most of the volunteers had been involved for just six months or less (Figure 3.19 a). A different pattern emerges when the individual CBM groups are plotted separately (Figure 3.19 b). All but one of the members of the WRG have been involved for 10 or more years, with most of them involved since its inception more than 12 years ago. On the other hand, the SLLT has plenty of new members, but very few who have been involved for any length of time.

a)

b)

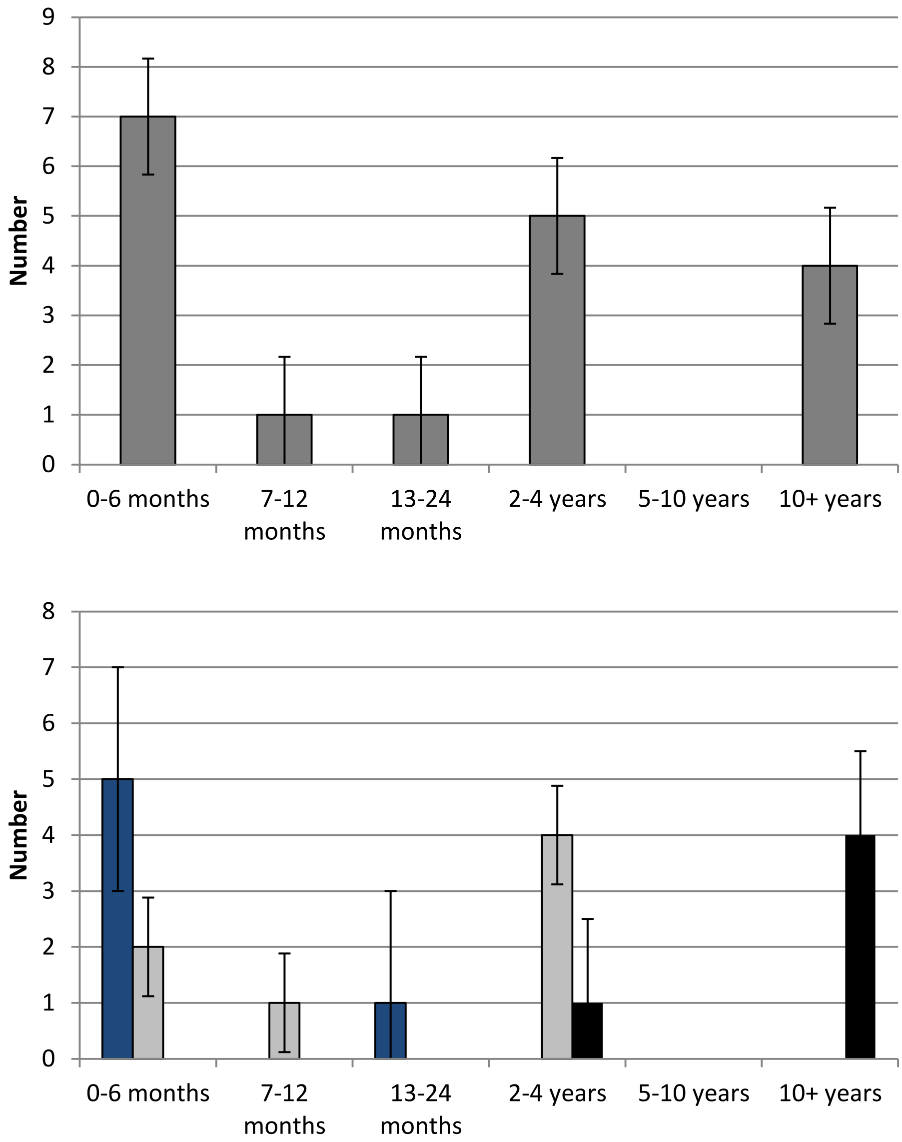


Figure 3.19: The length of time volunteers have been involved with their monitoring groups, a) all groups combined; b) split into individual groups; n = 18 (blue - SLLT; grey - Wai Care; black - WRG); (error bars ± standard error).

Members of the SLLT had the highest percentage of volunteers living within the catchment of the river they monitor (83%). Wai Care had the next most with 71%, while 60% of those involved with the WRG lived in the catchment. Volunteers who did not live in the catchment of their targeted waterway were also asked if they would rather take part in a programme, if one existed, located closer to where they live. Of the five people who did not live within the catchments, only one person said yes, and one person said they would take part in both the programme they are currently involved with, and the one closer to their home. The other three volunteers stated they would not for various reasons, including enjoying getting out to the site they monitor, and their involvement is through the school they teach in so they would still be involved in the programme regardless of where they lived.

The most common way the current volunteers found out about the programmes they are involved in was through a pamphlet or information delivered to their letter box. However, when broken down according to group, only members of the SLLT found out about their programme in this manner. Of the SLLT volunteers, 83% learned about the SLLT from letterbox drops while the remainder learned about it from talking to other members, and to others who knew about the programme. Volunteers from the other two groups learnt about their programmes from a variety of sources, including through work, school, university, from their children and through personal communication with members of the groups. No single method was significantly more or less popular than the others.

The most common reason for volunteers becoming involved in CBM was 'concern for the environment' with almost half the volunteers citing this as their main reason (Figure 3.20). Most of the volunteers gave two reasons for becoming involved, with the second reason often reflecting what field of work they are in and being very precise. An interesting difference between the groups was that no members of Wai Care state a reason for involvement as 'community involvement' while this reason featured relatively highly with both SLLT and WRG volunteers where this reason occupied 33% of the reasons given (Figure 3.20 b).

Members of the monitoring groups were asked what they hoped to achieve when they first started taking part in the monitoring. Most volunteers stated they wanted to gain education for themselves, help improve the environment or help enhance the community, including by strengthening their ties to the community (Figure 3.21). Only one volunteer did not set out to achieve anything when they first joined, rather they became involved because someone asked if they would, and have been involved ever since. This person is considered to be involved purely for 'simple involvement' in Figure 3.21. This volunteer has been involved with the WRG since its establishment 12 years ago. Of all the volunteers surveyed, only one believed they had not achieved what they wanted to at the time of their joining their monitoring group. Six people stated they had, while ten said they were still in the process of achieving their original goals. One individual, the aforementioned volunteer, did not set out to achieve anything specifically and therefore could not state if they had or had not achieved what they set out to.

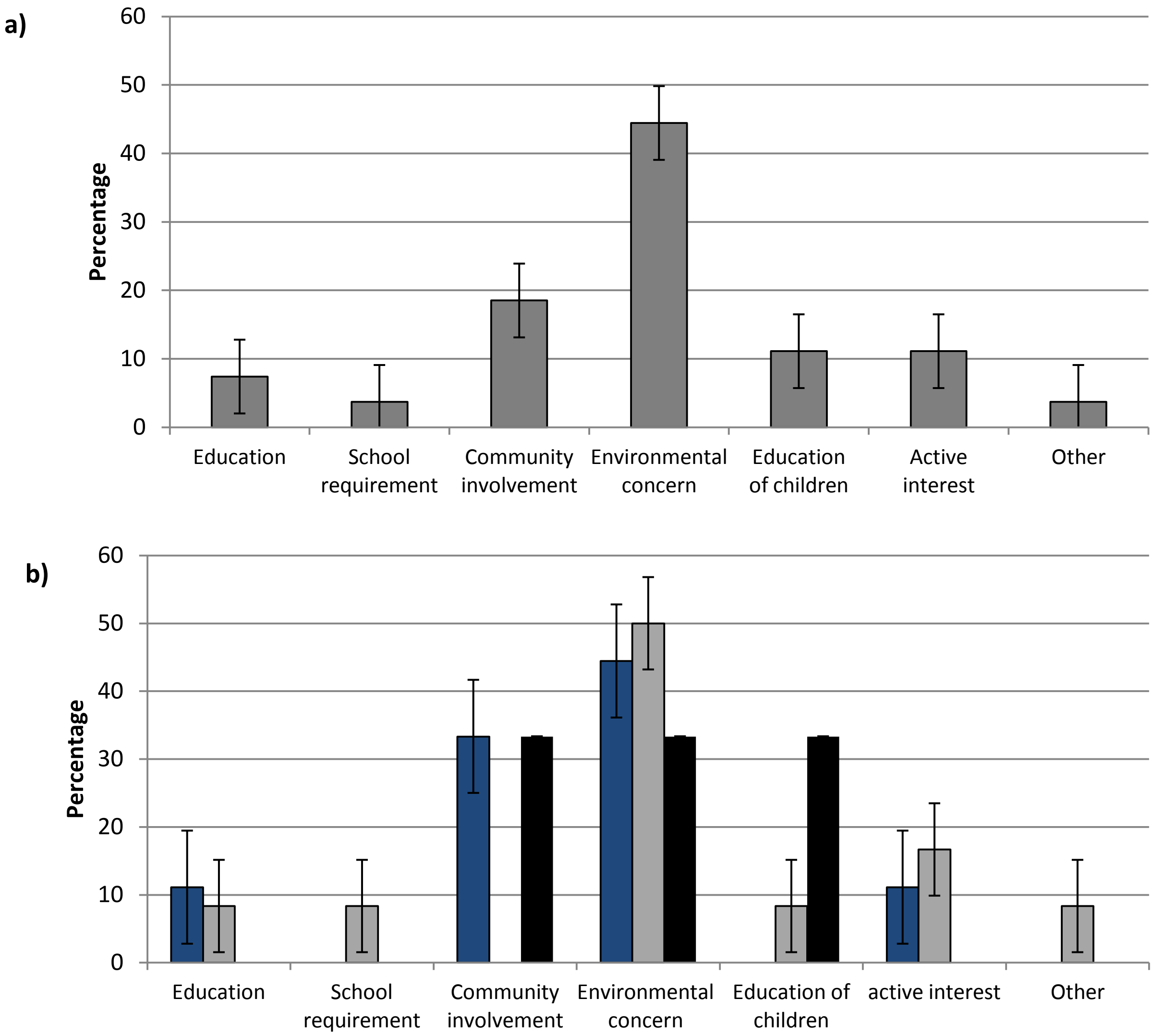


Figure 3.20: Reasons volunteers became involved with volunteer monitoring, a) all groups, b) according to each group; n = 27 (blue – SLLT, grey – Wai Care, black – WRG); (error bars ± standard error).

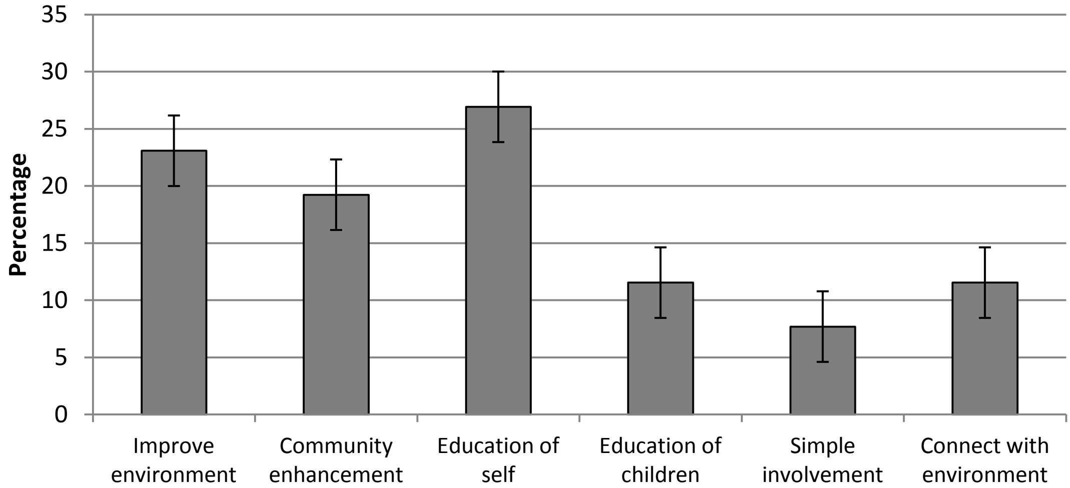


Figure 3.21: What volunteers hoped to achieve when they first became involved across all groups; n = 26, (error bars ± standard error).

3.4.3 Knowledge of Their Programme

Questions focused on the volunteer's knowledge of the programme they are participating in included aspects such as what methods they use when monitoring, and what they think the data is used for. The majority of volunteers (48%) believed the purpose of the monitoring programme was to monitor changes in the targeted rivers and tributaries over time (Figure 3.22), and to protect the environment (28%). The other purposes, while less popular, included community involvement and education which will occur while gathering data to monitor changes.

Volunteers were asked what they believed their data *was* used for (Table 3.2a) and most commonly responded that the data was used to monitor changes in the river over time, reflecting what they considered the purpose of the monitoring programme to be. There was more variety in the responses when asked what they thought the data *could* be used for (Table 3.2b) with responses including to monitor the effects of abstraction, set ecologically acceptable flows, compare data from before and after restoration or works, and to give the community ownership of any issues affecting the waterway .

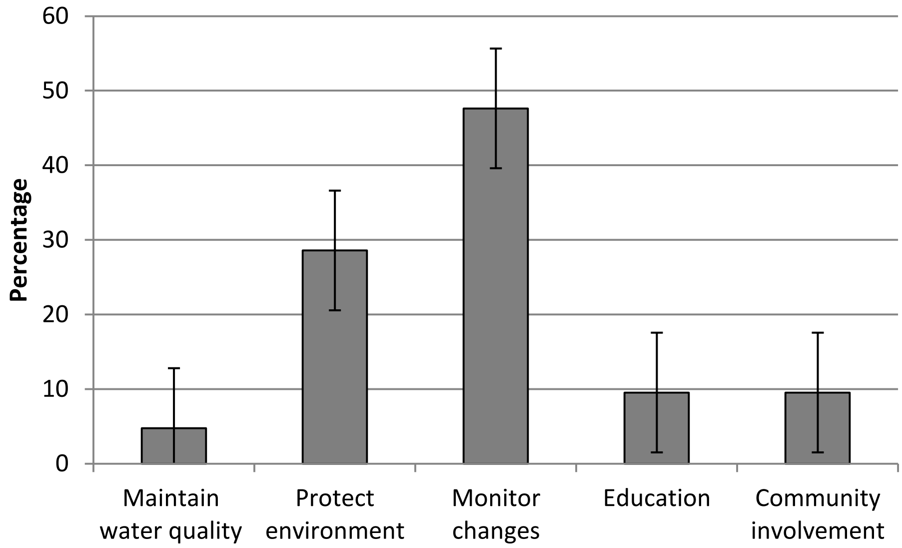


Figure 3.22: Volunteers opinions across all three groups regarding what the purpose of their monitoring programmes is; n = 21, (error bars ± standard error).

Table 3.2: Volunteers thoughts about what the data *is used for* (a) and what it *could be used for* (b). Each response was only stated by one or two volunteers.

a) What the data is used for currently	
Monitor changes in the river	Data available for public use
Pollution control	Build a database
Studies	Monitor for contamination
Put on the website	Nothing

b) What the data could be used for	
Comparisons with other waterways	Political issues
Build a database	Monitor changes in the waterway
Give ownership of the issues to the community	Use by city and regional councils
Development of baseline data	Compare before and after restoration/works
Set ecologically acceptable flows	Monitor effects of abstraction
Identify areas requiring improvement	Identify issues from changes in catchment
Education	Nothing

Coupled to the data purpose is the issue of quality. Many volunteers (44%) considered the data they collected to be of high enough quality to be used by professionals for scientific study and decision making, while only 6% (one person), did not think it was of high quality (Figure 3.23). However, 50% of the volunteers were unable to say decisively if it was, or was not, of high quality. These volunteers either thought there was potential for the data to be used by professionals, as long as there was some clarification as to who had collected the data and how it had been collected, or were unsure of its usefulness to professionals due to their perception that it was basic compared to professional data. There were no obvious differences in responses of the three groups.

Finally, volunteer's knowledge of what they are actually doing during each monitoring session was tested by asking them to name the parameters they measure and provide a brief explanation of each. All the volunteers could name at least half the parameters measured, however few were able to list all the parameters (Figure 3.24 a). There were differences between the different groups with over 70% of the Wai Care volunteers able to name all the parameters, but only 50% of the SLLT and 40% of WRG volunteers also able to do so (Figure 3.24 b). While 44% of the volunteers were able to provide reasonable explanations for each of the parameters, almost a quarter of the volunteers (Figure 3.25), consistently across all three groups, were unable to provide any explanations as to what these variables indicate about water quality.

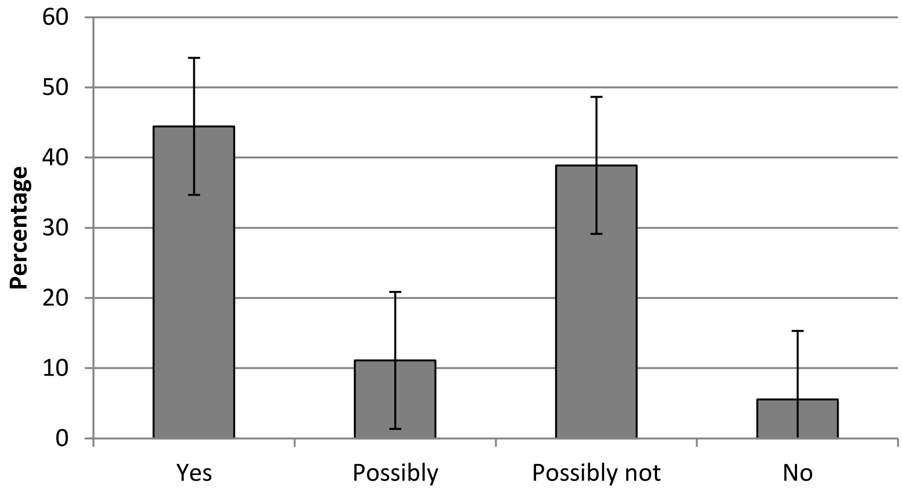
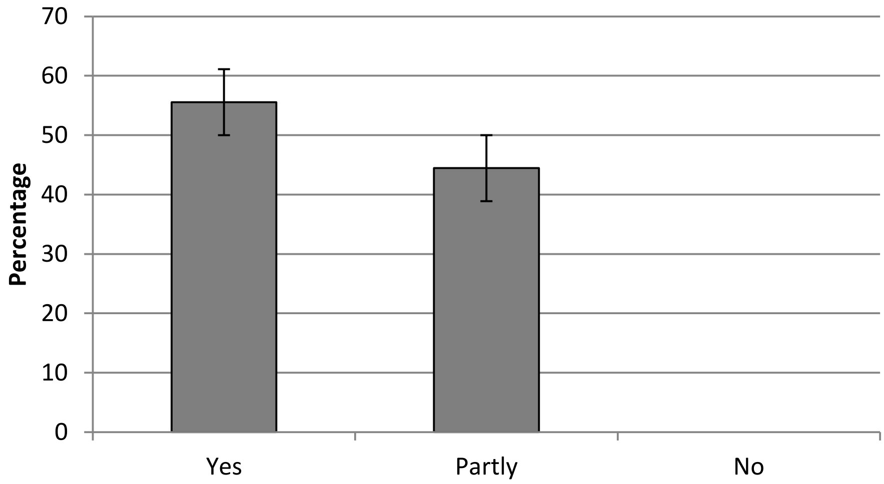


Figure 3.23: Responses across all groups to whether volunteers consider the data they collect to be of high enough quality to be used by professionals; n = 18 (error bars ± standard error).

a)



b)

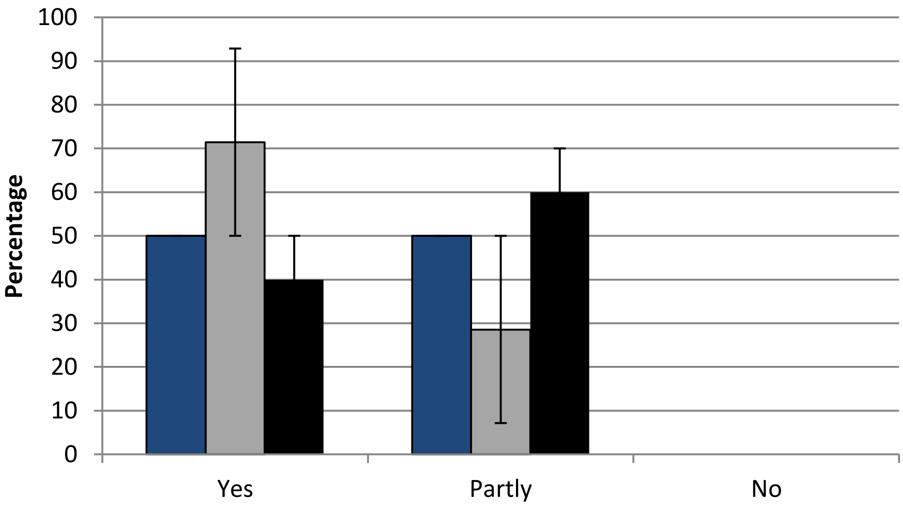


Figure 3.24: Responses to whether the volunteers could name all the parameters they measure at each monitoring occasion; a) all the groups combined; b) divided into the three CBM groups; n = 18, (error bars ± standard error, blue – SLLT, grey – Wai Care, black - WRG).

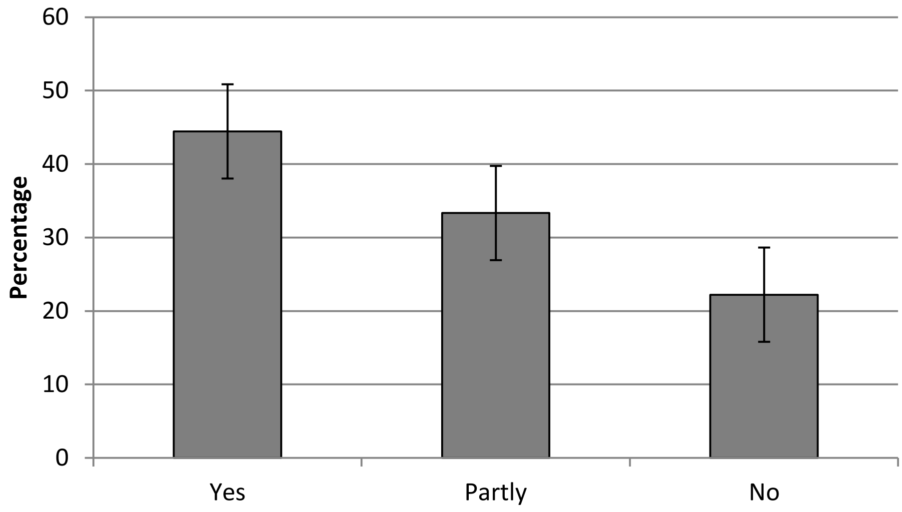


Figure 3.25: Could the volunteers accurately explain what each water quality parameter the measure means? n = 18, (error bars ± standard error).

3.4.4 Opinions of the Programmes

As the volunteers are the ones out in the field collecting the data, they were also asked if they could think of any ways to improve their programme. More than 80% of the volunteers answered 'yes' when asked if there were any aspects of the monitoring programmes that could be improved and clarified their answer with the suggestions listed in Table 3.3.

Volunteers were also asked about the volunteer experience as a whole and if anything could be done to improve it. Again, most volunteers (76%) said things could be done to improve the volunteer experience, and provided suggestions for improvement similar to those in Table 3.3. The two most popular responses related to a) improving training, so the volunteers were more confident carrying out the monitoring, and b) to getting more volunteers involved so that they were able to miss a monitoring session if necessary without leaving the other volunteers in the lurch.

Table 3.3: Ideas from the volunteers on how to improve the monitoring programmes. Ideas were only mentioned by one or two volunteers with no patterns of popularity.

Better equipment	Improved access to some monitoring sites
More advice from professionals	More analysis and feedback of results
Increased detail e.g. add more variables	Improved consistency e.g. same time, same people
More representative sites	Increased training and education
More provided information about water quality	More help from parents, other people

3.4.5 Volunteer Knowledge of Environmental Issues

The final part of the volunteer survey aimed to assess knowledge of freshwater issues, and environmental concerns in general, in New Zealand. With regard to New Zealand's freshwater issues, the most common concern was the high level of apathy prevalent in society (Figure 3.26). This was expressed as most people not caring enough about freshwater and the decline in quality as a direct result of this. Other common responses included the lack of effective legislation and rules governing the use of freshwater resources, and the impact of agriculture. Only one person believed New Zealand faced no major issues with regard to its freshwater. As with freshwater issues, volunteers considered apathy to be the most important issue the environment as a whole faces in New Zealand (Figure 3.27). Other issues again included agriculture and the government, but to a much lesser extent.

Notably, over 50% of the volunteers were involved with other environmental groups, with some being involved in more than one other group. These groups included Forest and Bird, the Ornithological Society of New Zealand, various tramping clubs, trout fishing clubs, A Rocha New Zealand, tree planting programmes and the Department of Conservation Kiwi Programme, as well as technical and professional groups such as the New Zealand Institute of Landscape Architects. There were no obvious differences between the three groups in this regard.

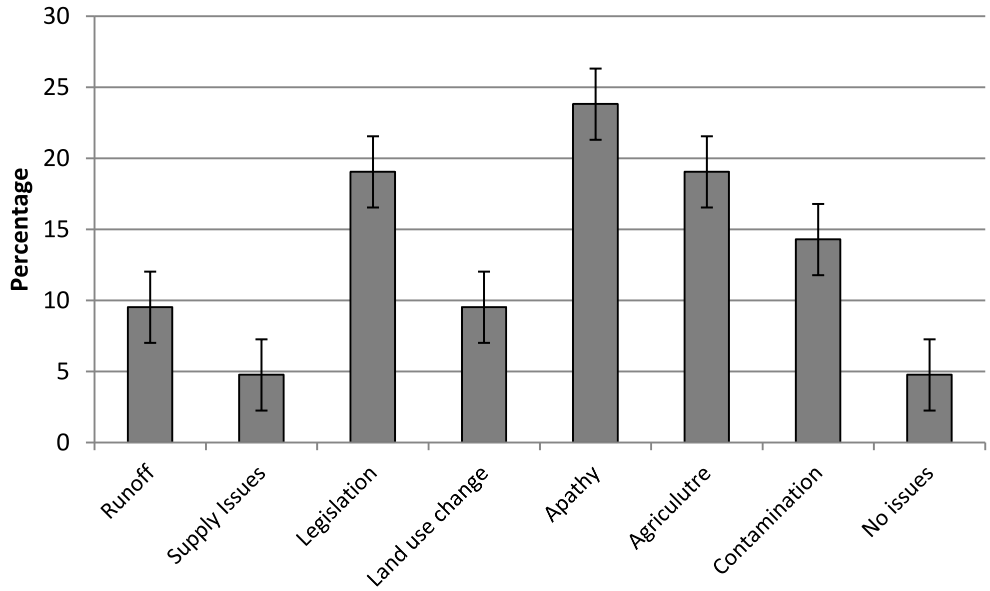


Figure 3.26: Volunteers opinions across all three groups about the most pressing issues with regard to freshwater in New Zealand; n = 26, (error bars ± standard error).

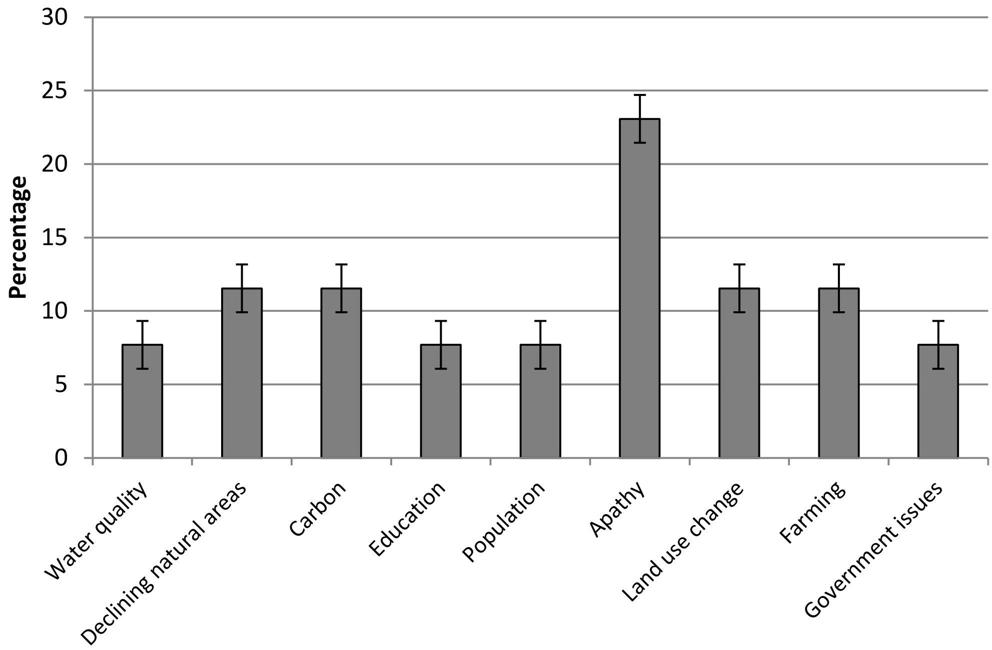


Figure 3.27: Volunteers ideas about the major issues the New Zealand's environment as a whole faces across all three groups; n = 26, (error bars ± standard error).

4 Discussion

The first interesting finding of this study was that only four groups were found that carry out routine water quality monitoring on a voluntary basis in New Zealand. This suggests the volunteer resource is underutilised and was surprising given that the country considering the widely accepted 'clean and green'. Community based programmes have been found to be efficient around the world for management and conservation (Grover 2006), and for the monitoring of freshwater resources (Donald 1997, Cuthill 2000, Whitelaw et al. 2003, Yarnell & Gayton 2003, Sharpe & Conrad 2006, Warburton & Gooch 2007). It is reasonable to assume their benefits can be experienced more widely within New Zealand, and this study has highlighted ways that the experience and data quality can be improved.

4.1 The quality of the volunteer data

4.1.1 pH

The pH data for all three of the CBM groups was very different from that of their professional counterparts. Following investigation into the methods used by the volunteers, including their equipment and monitoring protocols, a number of possible reasons for these differences were identified. Firstly, volunteers do not have access to the level of technical equipment available to professional groups. The very large difference between the pH strip and meter measurements (Figure 3.16) is cause for concern as two of the groups (WRG and Wai Care) rely on pH strips to generate pH data. When looking on the SLLT's pH strip container, no expiry date could be found. Therefore, the strips used in this comparison may be past their best and not measuring accurately. Despite the differences found, there is hope of improving the accuracy by utilising the pH meters employed by the SLLT. When calibrated, the pH meter results could not be statistically distinguished from the professional pH meter. These pH meters are both easy to use, and relatively inexpensive (costing around $130.00 each). At the end of the day, the calibrated meter was still accurately measuring the pH 7.00 standard to within 0.02 while the non-calibrated meter was measuring it as > 7.3. This emphasises the importance of meter calibration before each monitoring occasion. However, this should occur at least 24 hours before monitoring as there appeared to be some "memory" of the calibration pH for the first few measurements. This appeared in the form of a slightly larger difference between the calibrated and Waterways meter very early on in the day suggesting the pH meter "remembers" the final standard of pH 4 used in the calibration process. While this was not obvious in the statistical tests, it does suggest the pH meters should be calibrated early then thoroughly rinsed or soaked in freshwater following calibration.

Secondly, differences in the data set are likely to also have arisen as a result of the different times of day used for monitoring. In order to accurately compare pH measurements from one month, or year to the next, there must be some consistency with regard to the time of day measurement are taken. Figure 3.14 demonstrated the differences in pH at one site over the course of a single day, with more obvious even if the measurements are taken just one hour apart. This is a well known diurnal pattern observed for pH, water temperature and DO (Neal, et al. 2002, Tadesse et al. 2004). Prior to September 2011, the SLLT monitoring generally occurred across several different days of the week, and with no consistency in the time of day measurements were taken. For example in August 2009, of the 10 sites monitored, three sites were sampled on each of the 18th, 25th and 28th, and one on the 17th of August. The lack of consistency makes accurate comparison of the sites from month to month difficult.

The differences between the professional and volunteer data were relatively constant. The volunteer's data were regularly one or more pH units less than the professionals. If this is still the case when the same sample of water is measured using both the volunteer and professional methods (as was done for the SLLT data in this study), a correction could be added onto the volunteer value. For example, adding 1.5 onto the volunteer data generated by the WRG would bring each set more into line with the professional data. Statistical analysis of this corrected data reveals there would be no significant difference between the volunteer and professional monitoring data (Teal – $F_{92, 1} = 0.341$, $p = 0.561$; Kahikatea-Maori Pa Road – $F_{41, 1} = 2.930$, $p = 0.095$, Lower Lud – $F_{28, 1} = 3.073$, $p = 0.091$; Hira – $F_{26, 1} = 3.502$, $p = 0.073$).

4.1.2 Conductivity

Conductivity is monitored by the SLLT and the WRG and generally, volunteer data was slightly, but significantly less than the professional data. As with pH, this could be a product of the equipment available however, Figure 3.16 demonstrates only a small difference between an SLLT volunteer and a Waterways meter, a difference that was not significant. Differences between the volunteer and professional data may also be a product of site location. Some of the professional and volunteer sites used in a comparison were not as close to each other as is ideal. For example, there was a distance of approximately 1km between the WRG's Kahikatea site and the NCC's Maori Pa Road site, while both groups' sites at Hira are in essentially the same location. Natural variations in runoff and groundwater inputs over the course of a river may account for conductivity differences exhibited here. For example, the Styx River is dominated by spring inputs. As groundwater generally has higher conductivity than surface waters (Harvey et al. 1997), the influence of spring inputs may affect the conductivity. Conductivity is also influenced by stormwater runoff. Hatt et al. (2004) found conductivity increased with an increasing level of impervious surfaces in a catchment. The Styx catchment is currently a mix of urban and rural land use. Some data sets are likely to be affected by this, for example the comparison at Redwood Springs. The CCC's site is located adjacent to the Main North Road, while the SLLT's site is rural on the true left bank, and is an urban reserve on the true right.

Finally, tidal saline influence may also account for differences in the lower reaches. The comparison of the lower reach data from the Styx River yielded a significant difference for conductivity. The closer proximity of the CCC's site to the coast may indicate a larger effect of saltwater tidal intrusion as found in Westbrook's et al. (2005) study of estuarine river boundaries.

4.1.3 Water Temperature

With the exception one comparison, the professional and volunteer water temperature data could not be statistically differentiated. Temperature is a variable well understood and easily measured, compared to pH and conductivity for example. Protocols and methods are easier to follow, and most people will have measured temperature, before whether this was at school or university in a science lab, or just measuring body temperature if they are not feeling well. There are few ways volunteers can misreport or record a temperature reading.

One comparison did have data sets that were significantly different for volunteer and professional temperature data, the two sites compared on the Teal River, which may have had different bedrock substrates or riparian development. A study by Johnson (2004) found water that flowed over bedrock had a much greater range in temperature throughout the day. They also found riparian shading to have a major influence, with shaded sites having significantly different minimum and maximum temperatures, when compared to non shaded sites. As parts of the Teal Valley are in plantation forestry, the influence of shading on the river is difficult to assess. However, the other sites compared in the Wakapuaka catchment were either in the open, minimising the effects of shading, or both sites used for comparison were located at the same point and therefore have the same characteristics.

4.1.4 Turbidity (and clarity)

Turbidity values were determined using an equation to transform volunteer clarity values. Even before the transformation is carried out there were some inconsistencies that made the quality of the clarity values questionable. Clarity is measured visually by volunteers using a clarity tube. Measurements can vary between volunteers as eye sight strength also vary greatly. There is also a lack of consistent protocols with regards to taking a clarity measurement. For the SLLT, three readings are taken at each site, and then an average is calculated from these three values. However, some of the volunteers use one person to take three measurements, while others use two or three people to take a measurement each. Ideally, just one person should take all the clarity measurements all the time in order to radically decrease the variability of the measurements, but this is not practical. Therefore, standardising the measurement methods so all volunteers use the same protocols, would make comparisons between sites and months, much more accurate. However, studies have shown that water clarity is an accurate and simple way to determine turbidity and total suspended solids in a waterway (Anderson & Davic 2004, Dahlgren et al. 2004) and this method should be retained in volunteer monitoring.

Some of the inconsistencies may also be accounted for by who is monitoring, and how closely they follow the protocols set out for them. For example, the Hira site is monitored by for the WRG by Year Six pupils from Hira School. These children were observed to be very keen to get into the river to look at rocks and invertebrates and have fun, regardless of the order in which the monitoring should be carried out. Disturbance of the bed sediment decreases the clarity of the water, and this may account for the outliers and much larger variation compared to the professional data (Figure 3.8).

4.1.5 Dissolved Oxygen

DO is only measured by Wai Care volunteers. Similarities for parameter between the professional and volunteer data were obvious when viewed on the box plot (Figure 3.12) and no statistical difference was observed. However, lower values were often reported in the volunteer data (Figure 3.12). As with clarity, the volunteer's method to measure DO requires visual assessment and the comparison of two colours in order to determine the DO concentration in a sample. Like clarity, it is subject to variation amongst volunteers with different levels of eye strength. The difference between the volunteer and professional data for the earlier Wai Care data may also occur due to the distance between the professional and volunteer sites and inputs to the stream between these sites affecting DO. In the urban environment DO in streams can be affected by reduced baseflow (Walsh et al. 2005), sewage inputs, increased biological oxygen demand and stormwater runoff (Paul & Meyer 2001). All of these may be experienced to some degree between the volunteer site and Auckland Council's site further downstream. However, the similarity in volunteer and professional DO measurements at the more recent comparison (Figure 3.12 c) highlights its usefulness and should be investigated for use by the other volunteer groups.

4.1.6 Nitrate and Nitrite - Nitrogen

Wai Care also measures nitrogen in the form of nitrate and nitrite, using strips designed to monitoring swimming and spa pools. There was a significant difference found between volunteer and professional data for the earlier data, but there was no significant difference found in the newer data. This similarity in the more recent data bodes well for the continued use of this method, which is also cheap and easy to use. This finding is supported by a study conducted by Isbell et al. (2006) who determined there was a significant correlation in the measurements given by Aquachek nitrogen indicator strips, Wai Care's method of measuring nitrogen, and traditional laboratory methods. Nitrogen testing is not currently part of the SHMAK kit utilised by the SLLT and WRG, but should be considered for inclusion into these programmes. The fact that councils measure nitrate, nitrite or both combined, will make it reasonably easy to compare data sets and confirm reliability of the method. However, a more technical method of measuring nitrogen could also be investigated.

4.1.7 Water quality overall

These results only partially support those of a similar study carried out in Australia, assessing the accuracy of data collected by volunteers from Waterwatch Victoria (Nicholson et al. 2002). This study determined no significant differences between the volunteer data and that collected by the Victorian Water Quality Monitoring Network for the variables pH and electrical conductivity and for half of the turbidity comparisons. However, these comparisons had a much smaller data set, with measurements only spanning one year, and therefore had a lesser chance of detecting any statistical differences. Data set size limitations are discussed further on.

The Wai Care programme appeared to produce results that were the most similar to those of their professional counterparts. The inclusion of their DO and nitrogen methods into the SLLT and WRG programmes should be considered by their respective management teams.

4.2 SLLT Data: Trends and Interpretation

The data collected by the SLLT volunteers presents a large and almost continuous data set spanning 2005 to current day. The data has the potential to provide enough information to assess how the water quality has changed over time, and if coupled to a study of catchment use and how this has changed, it may also be possible to attribute reasons for these changes. For example, the development of large-scale subdivisions in the Styx Catchment has occurred in the past and will continue to occur in the future. They have the potential to alter river flows, sediment levels and chemical characteristics of the rivers. While monitoring of these effects is already carried out by the CCC and ECan, these data are not readily accessible for interested members of the public. This can be remedied by running a programme specifically for concerned community members and making results freely available and easy to understand.

4.2.1 Spatial Differentiation

The ten sites were compared to each other, with results demonstrating several important differences between the sites that were generally related to their geographic location within the catchment. This allowed the sites to be grouped into four distinct groups: 1) Head of the Catchment – Smacks Creek, Willowbank, Styx Mill; 2) Redwood Springs – Redwood Springs 1, 2 and 3; 3) Kaputone – Everglades Golf Course and Ouruhia Domain; 4) Lower reaches – Brooklands and Radcliffe Road. The sites at the head of the catchment are likely to be more heavily influenced by spring inputs, than runoff. Smacks Creek and Willowbank are both located on a tributary to the Styx River that originates in a semi rural area, only flowing through one small area of low density housing before flowing into the Styx River approximately 500 metres upstream of the Styx Mill site.

The intermittent inputs of spring sourced water have the potential to strongly influence the electrical conductivity of a river. The group at Redwood Springs was another group of sites that were statistically indistinguishable from each other but generally different from other sites. Again, the proximity of these sites to a major spring may account for this, due to the constant nature of the water flowing out of the spring and its influence on the water quality. These sites are also located within one kilometre of each other on a reach of the river under agriculture on the true left and residential development set back between 50 and 100 metres from the channel, on the true right.

Brooklands is situated very close to the river mouth and can potentially be affected by saline intrusion from the sea. However, it did not appear to differ from any of the other sites with the exception of those already mentioned, despite the fact that sea water has a higher electrical conductivity when compared to freshwater (Choudhury et al. 2001). The lack of apparent differences to the other sites suggests the tide gates in place just upstream of the mouth are effective at controlling the flow of saltwater upstream.

4.2.2 Temporal Trends

Visual assessment of the selected graphs over time (Figure 3.15) identified only a few meaningful trends. These included the seasonal cycling of water temperature and the possible seasonal cycling in conductivity measurements. The cycling of water temperatures on an annual basis is easily attributed to the cycling of air temperatures related to the seasons with the warmest water temperatures occurring in summer and the coolest in winter. The suggestion of a annual conductivity cycle may be a result of increased inputs of groundwater during the winter as a result of higher amounts of precipitation.

Other patterns identified included a possible increase in pH measurements from 2010 onwards. However, this increase coincides with the implementation of the use of the pH meters and therefore may just be a product of their higher degree of sensitivity, and possibly accuracy. However, if this trend continues over the next few years, it will become much more identifiable, and may become a cause for concern. There also appears to be an increase in water clarity. Those sites that did demonstrate an increase in clarity (Everglades Golf Course, Ouruhia Domain, and Redwood Springs 1, 2 and 3) all have established riparian vegetation, and are at least 50 meters from the nearest road or development. The increase in clarity suggests the riparian vegetation and apparent buffer zones are effective at intercepting and removing suspended solids from the waterway.

Analysis of the SLLT's data set revealed several single factors, and interactions between factors, that had a significant effect on the four predictors, at least in terms of statistics. Date and time had a significant effect on all four variables and supports the trends identified from the graphs. This accompanied by the results of the diurnal variation in pH (Figure 3.14) enforces the importance of sampling all sites on the same day and at approximately the same time as differences in weather and light can have a large influence.

There were several interactions between predictors that proved to have significant effects on the response variable. An interaction between date and time was significant for pH, conductivity and clarity, though interestingly, not for water temperature despite the well documented evidence of both of these factors on temperature. The lack of significance for water temperature is likely due to the high level of seasonal variation not accounted for in this model. There were no other noteworthy interactions prevalent in the models while those that were significant had very small effect sizes despite the high levels of significance suggesting there is very little effect of these predictors on the responses despite their levels of significance. It is likely that although these effects may be highly significant in terms of statistics, this does not indicate that there is a 'meaningful trend' in the data, or that it is relevant in a management situation (Scarsbrook 2006).

The SLLT data set analysed here was large with each of the 10 sites consisting of between 61 and 74 data points, with a total combined number of 675 individual measurements for each of the four variables. Measured statistical power is defined as the probability of detecting a change, or a difference, when a difference does exist (Thomas 1997, Crawley 2007). In general, large data sets have a much higher power, and therefore a higher likelihood of rejecting the null hypothesis, even if the actual differences are very small (Scarsbrook 2006). The large size of the data set provided by the SLLT increases the chance of rejecting the null hypothesis when it is actually true. This leads to the statistical test identifying significant trends or relationships when none exist. The large number of significant results computed during the analysis of the SLLT data set may just be a product of its large size, and are therefore not meaningful. Further investigation and analysis is required in order to determine the level of change that can be considered 'meaningful.'

If this is the case, and the large data set has indeed affected the trend analysis, it may be that few trends have occurred. Certainly no obvious negative trends were identified. This is a positive sign for the monitoring programme, for the Styx River and its tributaries, as no major negative changes in the four monitored variables have been detected over the past eight years, despite the evident land use changes that have occurred throughout the catchment.

Despite the low effect sizes, and the high probability of committing Type I errors, pH and water temperature proved to consistently have effect values larger than the other variables. This suggests that there may be, at the very least, a minimal effect on pH and water temperature with time over time. Should this monitoring programme lead to any remediation work or development of management plans, minimising the effect of pH and water temperature should be considered strongly in the development of these strategies. Both pH and water temperature have been shown to be affected by reduced channel flow (Dewson et al.2007), sediment, natural conditions (Winterbourn & Collier 1987, Young et al. 2005), urbanisation (Paul & Meyer 2001), and rural land uses (Wilcock et al. 2006), and therefore there will be several options that may decrease the changes in pH and water temperature in the catchment. These options could include more stringent controls on land use, modernising storm drain networks, and implementing the use of wide ranging riparian buffer zones among other things. All four variables have changed significantly over time, however, these changes are not currently large enough to be of any major concern, although, continued monitoring will identify if any concerns in the future need to be addressed.

4.3 The volunteers: involvement, knowledge and opinions

4.3.1 Volunteer Demographics

As noted earlier, it did prove to be difficult to find enough CBM groups in New Zealand that were still operating, as several had ceased to function over the last few years and there could be several reasons for this regression; a decline in the number of volunteers, loss of funding and lack of interest from the community. As a result of this, only 18 volunteers were able to be surveyed for this research, which was less than desired. However, due to the low numbers of groups, even having this many volunteers take part in the research was satisfactory.

There have been many published studies addressing the decline of volunteers in recent times (e.g. Smith 1999, Taniguchi 2006, Yanay & Yanay 2008). Several reasons are given including reduced interest, perceived rewards, and satisfaction, and increased demands from other commitments such as paid employment and family obligations. Almost 75% of the volunteers surveyed were female. This may be attributed to the traditional thought that men are the fulltime breadwinners in a family, leaving the women to take care of the home, children and their environment (Taniguchi 2006). However this notion is now becoming outdated as many women undertake fulltime paid employment as well as any household responsibilities. Therefore they can be considered to have less time for voluntary work than ever before. The dominance of women in these voluntary groups may also be attributed to the apparently higher incidences of altruism in women compared to men. Women and men favour different charities and voluntary organisations, with women tending to be more altruistic (Andreoni & Vesterlund 2001). Although much of the literature regarding differences in relationships to the environment, between the sexes, relates to developing nations (e.g. Leach

1992, Veuthey & Gerber 2010), the same principles can be applied to New Zealand. Generally women feel more involved and responsible for the environment and this may be reflected in the numbers of women involved with the water quality monitoring programmes.

One third of the volunteers were over 61 years of age, and only one volunteer was under the age of 20. While much of the literature focuses on the benefits to older, retired volunteers, research conducted in the United Kingdom found young people under the age of 24 are less likely to participate in voluntary work now, compared to any other time in the past (Smith 1999). The rate of volunteering may also decline in young people as they transition from adolescence to young adulthood, as a result of the loss of the school structure where opportunities to volunteer are presented on a regular basis (Wilson 2000). Certainly the only person under 20 years of age was involved as a result of a school activity. Children were not included in the survey, due to their young age, but were also involved in monitoring through their schools or organised activities such as Scouts. The high incidence of older individuals within voluntary groups has been attributed to older retirees having more time to volunteer, more future orientated world views and greater life experiences (Warburton & Gooch 2007). It has also been suggested that people in their middle age have the greatest incidence of volunteerism, as work and family obligations prompt social engagements such as sports teams, work social clubs and children's activities (Li & Ferraro 2006). This is supported in the data as some of the volunteers have become involved either through their children or through their place of employment.

Splitting the age group pattern up further revealed that within each of the three volunteer groups there are also patterns with regard to the age of volunteers. The majority of WRG volunteers fall in the age group 51 years or over while Wai Care volunteers are spread relatively evenly across the age categories. This is also reflected in the length of time the volunteers have been involved. When all the groups are combined into one graph (Figure 3.19a), the figure demonstrates most of the volunteers were either very new recruits (<1 year) or had been involved for a number of years (<5 years). However, when graphed separately (Figure 3.19b), most of the WRG volunteers have been involved for >10 years. As this group also has the largest group of volunteers over 51, it demonstrates their volunteers have become involved in their middle ages and stayed involved. Kulik (2007) found older volunteers experience higher levels of satisfaction and lesser amounts of burnout, when compared to younger volunteers. They attributed this to older volunteers having more life experience and therefore found it easier to overcome any difficulties that may be presented to them in the course of the voluntary work. The SLLT, on the other hand, have volunteers falling into two demographic groups. Their volunteers are either aged between 21 and 40, or over 61 years of age and none of the volunteers surveyed had been involved for longer than two years. This may demonstrate that the SLLT has difficulty retaining volunteers despite being very effective at recruiting them. Despite this, the SLLT does have members that have been involved for a number of years, however, many of these take part in the invertebrate monitoring programme which operates separately to the water quality monitoring and therefore were not part of this research.

Interestingly, more than 25% of the volunteers surveyed were immigrants, many of whom had moved to New Zealand for the 'clean green' lifestyle. The number of internationals compared to native born New Zealanders in these volunteer groups is high suggesting immigrants who have come here for the lifestyle and environment care more about the environment, or are just more willing to participate, than native born New Zealanders. One volunteer who grew up in the United States summed up their perceptions of the country before and after arriving in New Zealand:

> *"I think New Zealand is better than a lot of places but then the clean green thing is really going out the window when you go for hikes in the Waitakere's and stuff and you see the rubbish everywhere and people throwing plastic bottles. Everywhere you go, you could come back with a black sack of rubbish. It's just sad."*

Having come to New Zealand with expectations built around the global perception of New Zealand's greenness, the reality can be quite different which may shock many immigrants. This may motivate some of these immigrants into doing their part to improve the environment to a state they expected when they came here.

4.3.2 Volunteer Motivations and Barriers

Retaining volunteers is critical, as it reduces the need to recruit and train new volunteers, occupying time and money that could be more effectively utilised elsewhere in the programme (Grese et al. 2000, Ryan et al. 2001). While money is not so important in this study, as training can be provided by a more experienced volunteer during a monitoring occasion, this can only occur if there are volunteers available who are experienced and capable enough to provide the training. Retaining volunteers can be difficult as the material resources such as salary, bonuses and superannuation that provide motivation in organisations that work for profit, are not available (Boezeman & Ellemers 2008). Volunteers must therefore be satisfied in other ways, such as education, community involvement, meeting new people and making a difference for individuals or for groups of people. Volunteers who have higher levels of satisfaction are more likely to continue with their involvement.

This is important as excessive dropout can have fatal consequences for any volunteer organisation (Yanay & Yanay 2008).

Because of the lack of material incentives, reasons for becoming involved in one of the voluntary organisations in this study can range from very broad (e.g. wanting to help improve the environment), to very precise, (e.g. helping to improve a specific reach of a stream). Individual reasons for involvement generally reflected an individual's personal beliefs and interests. Concern for the environment was by far the most popular reason volunteers, over all three groups, chose to become involved. This is reasonably self explanatory, as if they were less concerned about the environment, but still wished to volunteer, they would choose a programme that reflected their own particular interests. Most people also gave a secondary reason for their involvement, and this generally reflected other interests and also the different fields volunteers worked in. For example, the teachers cited 'education of children' as one of their reasons, while another was using their involvement as a way to fulfil the community service section of a Duke of Edinburgh award being completed through their school. Many of the children involved including schools and Scout groups also participated in planting days and helped to remove rubbish from the streams and the surrounding areas (Figure 4.1). Their involvement in such activities, while not instigated by themselves, rather their teachers or leaders, will instil behaviour and habits they remember throughout their lives. It would be interesting to follow up with some of these children through adulthood to see if they are still involved with the environment.

Figure 4.1: Children from a Scout group take a break from monitoring to remove a shopping trolley from their monitored stream reach.

The fact that no Wai Care volunteers cited 'community involvement' (Figure 3.20 b) as a reason for taking part in the water quality monitoring was interesting, as this reason featured relatively highly in responses from the other two groups. This is possibly due to the nature of the three groups; the SLLT and WRG were established, and are run, by members of the community. Volunteers join, and work with other community volunteers on sites already established. On the other hand, Wai Care is run ultimately by Auckland Council, although regional coordinators are not necessarily council employees, and individuals join because they are interested in establishing monitoring sites at locations of interest to them. There appears to be less involvement with the wider community for the volunteers at Wai Care. Instead volunteers work with the same people at the same site each time, and therefore contact with others is minimal and generally limited to contact with their coordinator. Increased focus on the community, including presentations of the issues affecting the rivers and the results generated, in public meetings or to other community groups may help to remedy this. This may recruit new volunteers or at the very least raise the awareness of issues related to freshwater both in the Auckland region, and on a national basis.

4.3.3 How much do the Volunteers Know?

Several questions were asked of the volunteers in order to establish their state of knowledge about the programmes they are involved with. It may be crucial for volunteers to understand the ultimate goals and the desired outcome of a project (Grese et al. 2000) in order for them to get the most out of the programme, and be completely involved. Understanding these goals can make volunteers work more effectively. Almost half the volunteers thought the main purpose of the programme was to monitor changes in the river over time and believed the data was used for this purpose. However, to date, none of the data from any of the groups has been used for official or semi-official purposes as far as the author was able to find out. One response was that the data was available for use by the public, for use in processes such as planning and designing a new home. However, the public do not have direct access to this data without first contacting a member of the group and they may not even know this data exists unless they are already aware of the operation of these groups in their areas. Only one person believed the data was not used at all.

The lack of real use for the data could be a barrier to the continued involvement of volunteers and recruitment of new ones. Stukas et al. (2009) state that volunteer behaviour will ultimately decline if the targeted activities do not offer satisfaction or rewards, whether these be moral or material. A respondent in Warburton and Gooch's (2007) research stated they were experiencing stagnation until they realised the value of the environmental stewardship programme they were involved in.

Stagnation will also affect volunteers from these groups, especially when no feedback regarding results, changes and benefits is experienced. Ensuring the data has a purpose, whether it is used formally by councils or is just analysed and presented back to the volunteers, would help convey the notion that there is value in the CBM groups and in being involved.

Volunteers were also asked to consider what the data could be used for, in addition to its current functions. There was a reasonable amount of variety present in these responses. Data could be used to develop a baseline database, to enable comparison of the future state of the river or to monitor how long it takes for the river to return to what is considered a normal level following a contamination event, whether this be natural such as the recent earthquakes, or of anthropogenic origin such as a chemical spill. Another idea suggested giving the ownership of the issues back to the community. In theory, by making the community aware of any problems their local waterways are experiencing, they will become empowered to do something to affect changes for the better. However, in reality, not all members of the community will view this as an issue that affects them as an individual, therefore the onus will fall on a few, likely those that are already volunteering with these programmes or ones that are similar.

Generally, volunteer’s ideas regarding what the data could be used for reflected issues specific to their catchments. For example, volunteers that monitor or live near the Lud River have noted a decline in surface flow which they have attributed to the abstraction of water for domestic and stock purposes. Two members of the WRG considered the data could be used to set ecologically acceptable flows, and more generally, to monitor the effects of water abstraction on rivers. The Styx River catchment has experienced extensive land use change over the past decades, as land previously used for horticulture and agriculture is developed into residential sections. One volunteer suggested their data could be used to analyse how the quality of the river has changed as the catchment land use has changed. Another volunteer from Wai Care proposed their data could be used to determine if and how remediation and restoration projects affect the stream that has been targeted. All these ideas are possible and relatively easy to implement using existing data, but require a slightly different form of analysis, a person capable of helping with the analysis and locating data for the land use of the catchment. Like this research, many of these studies could be carried out by university students as part of a summer project, dissertation or thesis. Encouraging partnerships with universities, or with councils willing to sponsor the project, is one way to ensure the analysis is carried out.

Almost half the volunteers believed the data they collected was at a level of quality comparable to that of professionally collected data, and therefore could be used by professionals for activities such as decision making and scientific study. The remainder considered to the data to not be of high quality to compare to professional. In general, the volunteers that had at least some misgivings about the quality of the data collected, were currently employed in a science related field and arguably had a better idea of the type of data used by professionals like themselves. One volunteer currently working in the scientific industry stated:

> *"Being community based, there will always be some variation in consistency but this data can still provide an idea of what the water quality is and how it can be improved"*

There are ways to improve the accuracy, quality and consistency of volunteer generated data. For example, volunteers associated with Virginia Save our Streams in the US are required to complete a training and certification programme before taking part in monitoring (Engel & Voshell 2002). However, even in this situation, there are still concerns voiced by professionals that the training process is not rigorous enough to maintain the high standard of data required for management decisions and scientific study (Engel & Voshell 2002). These concerns must be addressed by all volunteer groups before environmental professionals can use their data with confidence. Some of the volunteers did voice concerns that if the data they collect was not considered accurate enough to be used for planning, decision making and study, what was the point in continuing to collect it? Conversely, some assumed the data was of high quality, because time and money would not be spent on a programme considered to generate inferior data. This again highlights the fact that volunteers must feel what they are doing is making a difference. If not, the groups are likely to experience a loss of volunteers and have difficulty attracting new ones. Enhanced training and education programmes for the volunteers of the groups used in this study would both provide confidence in the use of their data, and improve its quality.

4.3.4 Benefits the Volunteers Gain Through Their Involvement

One of the main aims of this research was to determine if volunteers involved with water quality monitoring programmes have gained education and knowledge that they would not have gained otherwise. Each volunteer was asked to list the water quality parameters measured during each monitoring occasion, and then provide a brief explanation of each variable. Every volunteer was able to name at least half of the parameters, however most of them forgot the visual assessments of riparian vegetation and streambed substrate that are carried out by all three groups. All volunteers did remember the physical parameters of pH, water temperature, clarity and either conductivity or

DO depending on which group they belonged to. Wai Care volunteers appeared to have a better knowledge of what the parameters were, although most deferred to the handbook provided by Wai Care that sets out the methods for monitoring. Without this handbook, some of the volunteers may not have been as accurate with the naming of the parameters. However, the fact that volunteers felt comfortable following these instructions, and referring to them, suggests the instructions and field guides are detailed enough, but still straightforward enough for non-scientists to use confidently.

When asked to provide an explanation of each parameter 44% of the volunteers were able to provide satisfactory explanations for each of the parameters they had already named. However, the majority of these volunteers worked in a science related field, and therefore probably already had the knowledge about these variables. Only two volunteers who could explain the parameters did not have scientific training. Almost a quarter of the volunteers were unable to provide any explanation, suggesting there is a lack of education about why they are carrying out the monitoring and what the monitoring means. Again, this relates back to volunteer engagement and satisfaction. Maintaining this through providing education, and experiences not generally available to lay, people keeps the volunteers interested, involved and empowered. Despite some of the volunteer's knowledge being less than ideal, they would still have a better idea about water quality than an individual not involved with any of the programmes.

Groups of school children are involved with the monitoring through the WRG (Hira School) and Wai Care (The Gardens School). These children proved to be well informed about issues with the environment and with freshwater according to their teachers. For example, on student at Hira School had said to their teacher:

> *"Don't let the cows go to the bathroom in [the river]"*

while another stated that to improve the health of the river, farmers need to:

> *"Fence [the river] off from animals"*

While they may have learnt about these issues in a classroom environment, these children are becoming more engaged by carrying out the monitoring themselves and are able to see, first hand, problems with their local river, their causes, and how they can be remedied. One teacher stated:

> *"One hopes it becomes a way of life for them"*

Involving children at a young age establishes and enforces good habits with regard to the environmental empathy. Any one of these children may be suitably captivated with the subject to pursue a career in the field, something they may not do if they were not given the early opportunity to be involved. Engaging children while they are young and interested will help to create a generation more environmentally aware than their parents, and who will hopefully make more progress on the issues the environment currently faces.

5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Quality of the data

The volunteer data was frequently significantly different from the professional data, with the exception of data for water temperature. Conductivity and pH were particularly problematic with their differences being uniformly large for all three volunteer groups. However, when the individual monitoring methods utilised by the SLLT were compared to professional methods, it became clear that it is not just the different equipment causing the differences, but is also the result of other factors such as variation in sampling methods, and in the time of day monitoring occurs. However, the most obvious differences were in pH measured with an indicator strip by volunteers. Accuracy could be improved with the use of pH meters as used by the SLLT. These results suggest it is predominantly the equipment and protocols that are responsible for the determined differences between the volunteer and professional data, rather than the quality of the volunteer data.

Clarity tubes were found to be an accurate, but simple and inexpensive method for determining water clarity, and therefore turbidity using an appropriate transforming equation. As clarity is one of the most recognisable measures of water quality, this can be easily and accurately assessed by members of the public and volunteers with little or no background in science and field work.

Wai Care's methods for measuring DO and nitrate and nitrite also generated data that could not be statistically differentiated from that generated by professionals. This bodes well for future use of their data, and their methods could be considered for inclusion in the other CBM programmes.

5.1.2 Changes in the Styx River

There has been little change in the water quality of the Styx River since the beginning of the data set in 2004. While statistical analysis did suggest some minor changes in pH, water temperature, conductivity and water clarity over time, these results may just be a product of the large data set, have no real repercussions from a management point of view. Statistical study did allow the SLLT catchment to be separated into four main sections where sites were most similar to each other, generally a result of features such as springs, tributaries and the estuary.

5.1.3 Volunteers

Generally, the volunteers were in their middle ages and were either very new volunteers (<6 months) or had been volunteering for a number of years (>5 years). Most volunteers chose to become involved with their monitoring group through their concern for the health of the environment. Volunteer's opinions regarding the quality of their data were reasonably evenly split between volunteers who considered their data to be of high quality, and those who didn't. Predominantly, those who questioned the quality of the data, had a background in science, or worked currently in a science related industry and also showed the greatest knowledge about programmes they were part of. Other volunteers displayed an occasional lack of understanding about the nature of their programme, but proved to have a wide understanding of issues for the environment and for freshwater. Apathy and agriculture were found to be to two issues most commonly identified by volunteers with them featuring highly in both the freshwater issues, and concerns about the environment as a whole.

Improving volunteer's access to information, education and training will not only increase the quality of the data but will benefit the volunteers as this is knowledge they would not gain otherwise. Increasing the quality of the data will in turn expand the uses of this data as it becomes more trusted by officials. Keeping volunteers interested and motivated to stay involved will go a long way towards the longevity and effectiveness of these CBM groups.

5.2 Recommendations

The final objective of this study was to provide a list of guidelines and suggestions for improving the quality of data and experiences for the volunteers. It will be possible for the quality of the data to be improved rendering it more useful for professionals and scientists to use for study, planning and decision making (Figure 5.1), which will provide motivation for the volunteers. The volunteers gain more knowledge and experience which again helps to improve the quality of the data, and put the data and therefore the group that generates the data further into the spotlight (providing they are justly identified as the source of the data). The publicity will ensure they become more known a wider range of individuals become aware of the programme, with some of these becoming involved also. These better data quality will have knock on effects to result in a more accurate and representative monitoring programme that receives more support.

There are also potential ways to combat real and perceived barriers, and to maximise the incentives for volunteering. Actively promoting incentives such as community connectedness and the opportunity to acquire knowledge and participate in activities not normally available to the public, are important actions that can help to both recruit new volunteers, and retain current ones. Barriers can also be overcome through initiatives such as car pooling, organised social activities in order for volunteers to get to know each other, continued new education opportunities and tangible appreciation for what the volunteers do.

Specific recommendations to achieve these outcomes are listed below.

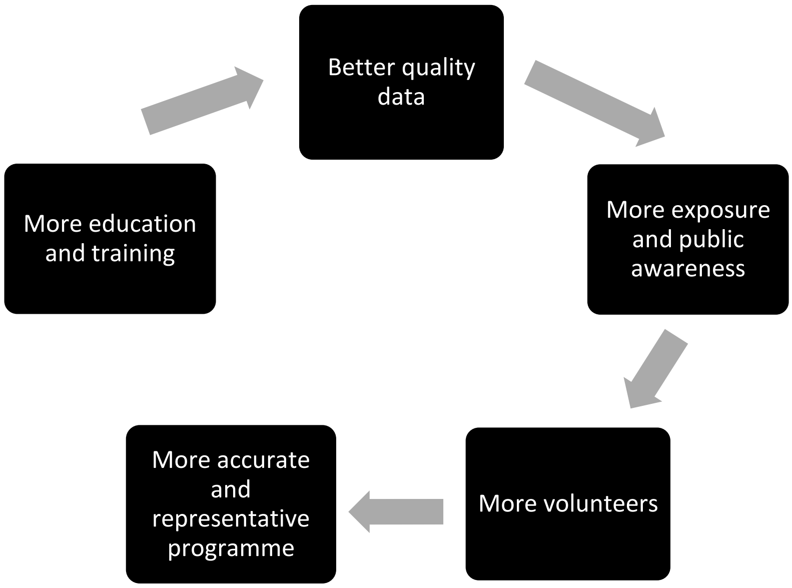


Figure 5.1: The path to better quality data and a more precise monitoring programme as proposed by this study

5.2.1 For Improved Data Quality

1. Utilise more rigorous monitoring protocols (e.g. standardised monitoring times, have at least some the same people monitoring the same sites each time, and have a set order for parameter measurements).
2. Hold regular training days and information sessions to ensure volunteer skills are maintained and new volunteers are competent with the protocols, before carrying out monitoring themselves.
3. Ensure each volunteer is provided with information about the goals of the programme, why each variable is monitored and what each variable means with regard to water quality.
4. Provide each volunteer (or monitoring kit) with a booklet with detailed protocols for monitoring.

5. Investigate the feasibility of using better quality equipment, for example the YSI Ecosense pH meters could be used by Wai Care and the WRG as they are easy to use, reasonably low in price and provide more accurate data than the pH strips.
6. Improve maintenance of the equipment that is available (e.g. the manual for the TDScan WP3 Conductivity meters used by the WRG and SLLT suggests the electrodes are periodically cleaned by rinsing in alcohol for 10-15 minutes).
7. Investigate the possibility of adding a correction to the pH and conductivity data, if the volunteer monitoring data is consistently measured to be different by the same amount when compared to the professional equipment.
8. Thoroughly rinse monitoring equipment in freshwater following calibration to avoid the electrode retaining a 'memory' of the calibration standards, and store in freshwater for 24 hours.

5.2.2 For Improved Volunteer Experience

1. Annual basic analysis and presentation of the data to the volunteers, so that they can see any trends. This could be carried out in conjunction with training, information and education sessions.
2. Annual or as required information sessions about the monitoring programme (why, how, goals, patterns, what the parameters show about water quality), as volunteers who are more aware of the purpose, are likely to be more careful during monitoring.
3. Contact with other volunteer monitoring groups. The volunteers surveyed in this study all wanted to know what other groups are doing. Contact could be in the form of emails, video conferences, sharing of information or a biannual (or other appropriate interval) conferences with guest speakers, data analysis and workshops.
4. Increased emphasis on community involvement and enrichment through aspects such as presentations to other community groups and schools, public information sessions, planting days, presence at community events such as school fairs and fun days.
5. Social events allowing volunteers to get to know each other, and bring friends and family, outside of the regular monitoring sessions.

5.2.3 For recruitment and maintenance of volunteers

1. Inclusion of school children encourages a generation of environmentally-aware children and involves parents, some of which may chose to stay involved once their class or children's involvement has ended.

2. Sharing results with volunteers, so that they can be discussed among friends and family, possibly attracting new members.
3. Increased public awareness of the programme through features in local newspapers, talks to community groups, or letterbox material.

5.2.4 Recommendations for the SLLT

As the SLLT were engaged with more closely than the other groups in this research, some additional recommendations pertain specifically to them;

1. Explore the use of some of the monitoring equipment used by Wai Care, specifically the methods to measure DO and nitrogen.
2. Approach schools in the catchment to offer them the chance to take part in the monitoring programme, as occurs with the WRG and with Wai Care. There are several schools in very close proximity to the Styx River and its tributaries, including Harewood School, Breens Intermediate, Emmanuel Christian School, Redwood School, Belfast School, Marshland School and Ouruhia School.
3. Regular (annual or semi-annual) letterbox drops of information about the Trust and how to become involved. This has proved a very effective method for attracting volunteers for the SLLT in the past so it should be continued if possible.

5.2.5 Recommendations for Further Study

The limitations of this study have been recognised (Section 2.5). Further study may be able to address these. For example;

1. Conduct comparisons of the Wai Care monitoring tools, specifically the DO, nitrogen and phosphorus kits, with the methods commonly utilised by professionals.
2. Extend the survey to members of volunteer groups that carry out other forms of environmental monitoring, to ascertain the state of environmental volunteering in New Zealand
3. Compare New Zealand's volunteer groups to those that are more established and prevalent in Australia, the US and Canada, carrying out the same kind of analysis on their data and volunteers. Analysing these groups, and implementing their ideas and protocols used by these groups, and maintaining contact with them, may help to increase the quality of data, number of volunteers and overall experience for the New Zealand groups.

6 Reference List

Ailamaki, A., Faloutos, C., Fischbeck, P. S., Small, M. J. & van Briesen, J., (2003), 'An environmental sensor network to determine drinking water quality and security', *SIGMOD Record*, **32**(4): 47-52.

Anderson, P. & Davic, R. D., (2004), 'Use of transparency tubes for rapid assessment of total suspended solids and turbidity in streams', *Lake and Reservoir Management*, **20**(2): 110-120.

Andreoni, J. & Vesterlund L., (2001), 'Which is the fair sex? Gender differences in altruism', *The Quarterly Journal of Economics*, **116**(1): 293-312.

Arnone, R. D. & Walling, J. P., (2007), 'Waterborne pathogens in urban watersheds', *Journal of Water and Health*, **5**(1): 149-162.

Audubon, (2012), 'Christmas Bird Count', retrieved 26 November, 2012, from http://birds.audubon.org/christmas-bird-count

Australian Government, (2007), 'About Waterwatch Australia', retrieved 21 March, 2013, from http://www.waterwatch.org.au/about.html.

Ballantine, D. J. & Davies-Colley, R. J., (2010), *Water quality trends at NRWQN sites for the period 1989-2007*, NIWA Client Report: HAM2009-026, Ministry for the Environment, Wellington.

Bash, J. S. & Ryan, C. M., (2002), 'Stream restoration and enhancement projects: is anyone monitoring?', *Environmental Management*, **29**(6): 877-885.

Bates, D., Maechler, M. & Bolker, B., (2012), 'lme4: Linear mixed-effects models using S4 classes', R package version 0.999999-0. http://CRAN.R-project.org/package=lme4.

Bengraïne, K. & Marhaba, T. F., (2003), 'Using principal component analysis to monitor spatial and temporal changes in water quality', *Journal of Hazardous Materials*, **100**: 179-195.

Berka, C., Schreier, H. & Hall, K., (2001), 'Linking water quality with agricultural intensification in a rural watershed', *Water, Air, and Soil Pollution*, **127**: 389-401.

Berry, J., Fleischer, L., Hart, W., Phillips, C. & Watson, J., (2005), 'Sensor placement in municipal water networks', *Journal of Water Resources Planning and Management*, **131**(3): 237-243.

Biggs, B. J. F., (1995), 'The contribution of flood disturbance, catchment geology and land use to the habitat template of periphyton in stream ecosystems', *Freshwater Biology*, **33**: 419-438.

Bjorkland, R. & Pringle C. M., (2001), 'Educating our communities and ourselves about conservation of aquatic resources through environmental outreach', *Bioscience*, **51**: 279-282.

Boezeman, E. J. & Ellemers, N., (2008), 'Volunteer recruitment: the role of organizational support and anticipated respect in non-volunteers' attraction to charitable volunteer organizations', *Journal of Applied Psychology*, **93**(5): 1013-1026.

Bonate, P. L., (2011), 'Linear Mixed Effects Models', in *Pharmacokinetic-Pharmacodynamic Modelling and Simulation, Second Edition*', Springer, New York.

Boyd, C. E., (2000), *Water quality: an introduction*, Kluwer Academic Publishers, Boston.

Brabec, E., Schulte, S. & Richards, P. L., (2002), 'Impervious surfaces and water quality: a review of current literature and its implications for watershed planning', *Journal of Planning Literature*, **16**(4): 499-514.

Bradshaw, B., (2003), 'Questioning the credibility and capacity of community-based resource management', *Canadian Geographer*, **47**(2): 137-150.

Brett, M. T., Arhonditsis, G. B., & Mueller, S. E., (2005), 'Non-point-source impacts on stream nutrient concentrations along a forest to urban gradient', *Environmental Management*, **35**: 330-342.

Brisbois, M. C., Jamieson, R., Gordon, R., Stratton, G. & Madani, A., (2008), 'Stream ecosystem health in rural mixed land-use watersheds', *Journal of Environmental Engineering and Science*, **7**: 439-452.

Camargo, J. A. & Alonso, A., (2006), 'Ecological and toxological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment', *Environment International*, **32**: 831-849.

Canfield Jnr, D. E., Brown, C. D., Bachmann, R. W. & Hoyer, M. V., (2002), 'Volunteer lake monitoring: testing the reliability of data collected by the Florida LAKEWATCH program', *Lake and Reservoir Management*, **18**(1): 1-9.

Choudhury, K., Saha, D. K. & Chakraborty, P., (2001), 'Geophysical study for saline water intrusion in a coastal alluvial terrain', *Journal of Applied Geophysics*, **46**(3): 189-200.

Christchurch City Council, (2012), 'Styx Harbour Road (CCC) – River Stage height (metres)', retrieved 27 November, 2012, from http://ecan.govt.nz/services/online-services/monitoring/river-flows/Pages/river-flow-chart.aspx?SiteNo=66422.

Christie, J., (2004), 'Volunteer attitudes and motivations: research findings and their application for sustainable community involvement programs in natural resource management', paper presented at *Effective Sustainability Education: What Works? Why? Where Next? Linking Research and Practice Concurrent*, Sydney, Australia.

Clair, T. A. & Hindar, A., (2005), 'Liming for the mitigation of acid rain effects in freshwaters: a review of recent results', *Environmental Reviews*, **13**: 91-128.

Clapcott, J. E., Collier, K. J., Death, R. G., Goodwin, E. O., Harding, J. S., Kelly, D., Leathwick, J. R. & Young, R. G., (2012), 'Quantifying relationships between land-use gradients and structural and functional indicators of stream ecological integrity', *Freshwater Biology*, **57**: 74-90.

Clinton, B. D. & Vose, J. M. (2006), 'Variation in stream water quality in an urban headwater stream in the southern Appalachians, *Water, Air, and Soil Pollution*, **169**: 331-353.

Cohn, J. P., (2008), 'Citizen science: can volunteers do real research?', *BioScience*, **58**(3): 192-197.

Collier, K. J., & Clements, B. L., (2011), 'Influences of catchment and corridor imperviousness on urban stream macroinvertebrate communities', *Hydrobiologia*, **664**: 35-50.

Conrad, C. C. & Hilchey, K. G., (2011), 'A review of citizen science and community-based environmental monitoring: issues and opportunities', *Environmental Monitoring and Assessment*, **176**: 273-291.

Cooper, A. B. & Thomsen C. E., (1988), ‘Nitrogen and phosphorus in streamwaters from adjacent pasture, pine, and native forest catchments’, *New Zealand Journal of Marine and Freshwater Research*, **22**(2): 279-291.

Cope, M., (2010), ‘Coding Qualitative Data’, in Hay, I. (ed), *Qualitative Research Methods in Human Geography, Third Edition*, Oxford University Press, Canada.

Costa, J. L., Massone, H., Martínez, D., Suero, E. E., Vidal, C. M. & Bedmar, F., (2002), ‘Nitrate contamination of a rural aquifer and accumulation in the unsaturated zone’, *Agricultural Water Management*, **53**: 33-47.

Coulter, C. B., Kolka, R. K. & Thompson, J. A. (2004), ‘Water quality in agricultural, urban, and mixed use watersheds’, *Journal of the American Water Resources Association*, **40**(6): 1593-1601.

Crawley, M. J., (2007), ‘The R Book’, John Wiley & Sons, England.

Cullen, R., Hughey, K. & Kerr, G., (2006), ‘New Zealand freshwater management and agricultural impacts’, *The Australian Journal of Agricultural and Resource Economics*, **50**(3): 327-346.

Cuthill, M., (2000), ‘An interpretive approach to developing volunteer-based coastal monitoring programmes, *Local Environment: The International Journal of Justice and Sustainability*, **5**(2): 127-137.

Dahlgren, R., Van Nieuwenhuyse, E. & Litton, G., (2004), ‘Transparency tube provides reliable water-quality measurements’, *California Agriculture*, **58**(3): 149-153.

Davies-Colley, R. J., Hickey, C. W., Quinn, J. M. & Ryan, P. A., (1992), ‘Effects of clay discharges on streams 1: Optical properties of epilithon’, *Hydrobiologia*, **248**: 215-234.

De Vaus, D., Gray, M. & Stanton, D., (2003), ‘Measuring the value of unpaid household, caring and voluntary work of older Australians’, Australian Institute of Family Studies, Research Paper 34.

Dewson, Z. S., James, A. B. W. & Death, R. G., (2007), ‘Invertebrate community responses to experimentally reduced discharge in small streams of different water quality’, *Journal of the North American Benthological Society*, **26**(4): 754-766.

Donald, B. J., (1997), ‘Fostering volunteerism in an environmental stewardship group: a report on the task force to bring back the Don, Toronto, Canada, *Journal of Environmental Planning and Management*, **40**(4), 383-505.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z-I., Knowler, D. J., Lévêque, C., Naiman, R. J., Prieur-Richard, A-H., Soto, D, Stiassny, M. L. J. & Sullivan, C. A., (2006), ‘Freshwater biodiversity: importance, threats, status and conservation challenges’, *Biological Reviews of the Cambridge Philosophical Society*, **81**(2): 163-182.

Dunn, S. M., Stalham, M., Chalmers, N. & Crabtree, B., (2003), ‘Adjusting irrigation and abstraction to minimise the impact on stream flow in the East of Scotland’ *Journal of Environmental Management*, **68**(1): 95-107.

Employment and Family Characteristics’, *Nonprofit and Voluntary Sector Quarterly*, **35**(1): 83-101.

Engel, S. R. & Voshell Jnr, J. R. (2002), ‘Volunteer biological monitoring: can it accurately assess the ecological condition in streams?’, *American Entomologist*, **48**: 164-177.

Environment Canterbury, (2012), 'Styx Radcliffe Road – River flow (cubic metres per second)', retrieved 27 November, 2012, from http://ecan.govt.nz/services/online-services/monitoring/river-flows/Pages/river-flow-chart.aspx?SiteNo=66425.

Eriksson, E., Baun, A., Scholes, L., Ledin, A., Ahlman, S., Revitt, M., Noutsopoulos, C. & Mikkelsen, P. S. (2007), 'Selected stormwater priority pollutants — a European perspective', *Science of the Total Environment*, **383**: 41-51.

Fore, L. S., Paulsen, K. & O'Laughlin, K., (2001), 'Assessing the performance of volunteers in monitoring streams', *Freshwater Biology*, **46**: 109-123.

Forsyth, P.J., Barrell, D.J.A. & Jongens, R., (2008), 'Geology of the Christchurch area', Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand.

Galbraith, L. M. & Burns, C. W., (2007), 'Linking land-use, water body type and water quality in southern New Zealand', *Landscape Ecology*, **22**: 231-241.

Gannon, V. P. J., Duke, G. D., Thomas, J. E., Van Leeuwen, J., Byrne, J., Johnson, D., Kienzle, S. W., Little, J., Graham, T. & Selinger, B., (2005), 'Use of in-stream reservoirs to reduce bacterial contamination of rural watersheds', *Science of the Total Environment*, **348**: 19-31.

Gnecco, I., Berretta, C., Lanza, L. G. & La Barbera, P., (2005), 'Storm water pollution in the urban environment of Genoa, Italy', *Atmospheric Research*, **77**: 60-73.

Gore, A., (1992), 'Earth in the Balance: Ecology and the Human Spirit', Houghton Mifflin, Boston.

Gouveia, C., Fonseca, A., Câmara, A., & Ferreira, F., (2004), 'Promoting the use of environmental data collected by concerned citizens though information and communication technologies', *Journal of Environmental Management*, **71**: 135-154.

Grayman, W. M., Loucks, D. P. & Saito, L., (2012), 'Stressors influencing our future visions', in Grayman, W. M., Loucks, D. P. & Saito, L., (eds), *Toward a sustainable water future*, ASCE, Virginia.

Grese, R. E., Kaplan, R., Ryan, R. L. & Buxton, J., (2000), 'Psychological benefits of volunteering in stewardship programs', in Gobster, P. H. & Hill, R. B. (eds), *Restoring Nature: perspectives form the social science and humanities*, Island Press, Washington DC.

Grover, V., (2006), 'Introduction', in *Water: global common and global problems*, Grover, V. (ed), Science Publishers, Enfiled NH USA.

Hamilton, D., (2005), 'Land use impacts on nutrient export in the Central Volcanic Plateau, North Island', *New Zealand Journal of Forestry*, **49**: 27-31.

Harvey, F. E., Lee, D. R., Rudolph, D. L. & Frape, S. K., (1997), 'Locating groundwater discharge in large lakes using bottom sediment electrical conductivity mapping', *Water Resources Research*, **33**(11): 2609-2615.

Hatt, B. E., Fletcher, T. D., Walsh, C. J. & Taylor, S. L., (2004), 'The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams', *Environmental Management*, **34**(1): 112-124.

Hills, D. & Hills, H., (2006), 'Settling Near the Styx River', D. A. & H. J. Hills, Christchurch.

Hills, D., (2002), '*The Styx Story: a Study of a Christchurch River*', Styx History Group, Christchurch.

Hooda, P. S., Edwards, A. C., Anderson, H. A. & Miller, A., (2000), 'A review of water quality concerns in livestock farming areas', *Science of the Total Environment*, **250**: 143-167.

Hussainy, S. U. & Kumar, S., (2006), 'Freshwater – a scarce resource: its global utilization and sustainable work practices in Melbourne, Australia', in *Water: global common and global problems*, Grover, V. (ed), Science Publishers, Enfiled NH USA.

Institute of Geological and Nuclear Sciences, (1998), 'Nelson: 1:250 000 Geological Map 9', retrieved 28 November, from http://www.gns.cri.nz/Home/Our-Science/Earth-Science/Regional-Geology/Geological-Maps/1-250-000-QMAP/

Institute of Geological and Nuclear Sciences, (2001), 'Auckland: 1:250 000 Geological Map 9', retrieved 28 November, from http://www.gns.cri.nz/Home/Our-Science/Earth-Science/Regional-Geology/Geological-Maps/1-250-000-QMAP/

Institute of Geological and Nuclear Sciences, (2008), 'Christchurch: 1:250 000 Geological Map 16', retrieved 28 November, from http://www.gns.cri.nz/Home/Our-Science/Earth-Science/Regional-Geology/Geological-Maps/1-250-000-QMAP/

Interlandi, S. & Crockett, C. S., (2003), 'Interlandi S, Crockett CS (2003) Recent water quality trends in the Schuylkill River, Pennsylvania, USA: A preliminary assessment of the relative influences of climate, river discharge and suburban development', *Water Research*, **37**: 1737–1748.

Isbell, F. I., Mercer, D. R. & Iqbal, M. Z., (2006), 'Reliability of water quality test strips for field measurement of nutrients essential for developing mosquito larvae', *Journal of American Undergraduate Research*, **5**(2): 1-8.

Jensen, F. B., (2003), 'Nitrite disrupts multiple physiological functions in aquatic animals', *Comparative Biochemistry and Physiology Part A*, **135**: 9-24.

Johnson, S. L., (2004), 'Factors influencing stream temperatures in small streams: substrate effects and a shading experiment', *Canadian Journal of Fisheries and Aquatic Sciences*, **61**: 913-923.

Kaiser, F. G., Ranney, M., Hartig, T. & Bowler, P. A., (1999), 'Ecological behaviour, environmental attitude, and feelings of responsibility for the environment', *European Psychologist*, **4**(2): 59-74.

Kalbus, E., Reinstorf, F. & Schirmer, M., (2006), 'Measuring methods for groundwater-surface water interactions: a review', *Hydrological and Earth System Sciences*, **10**: 873-887.

Kaltenborn, B. P. & Bjerke, T., (2002), 'Associations between environmental value orientations and landscape preferences', *Landscape and Urban Planning*, **59**: 1-11.

Kim, J. P., Hunter, K. A. & Reid, M. R., (1999), 'Geochemical processes affecting the major ion composition of rivers in the South Island, New Zealand', *Marine and Freshwater Research*, **50**: 699-709.

Knobelock, L., Salna, B., Hogan, A., Postle, J. & Anderson, A., (2000), 'Blue babies and nitrate-contaminated well water', *Environmental Health Perspectives*, **108**(7): 675-678.

Kondolf, G. M. & Micheli, E. R., (1995), 'Evaluating stream restoration projects', *Environmental Management*, **19**(1): 1-15.

Krosnick, J. A. & Presser, S., (2010), 'Question and questionnaire design', in Marsden, P. V. & Wright, J. D. (eds), *Handbook of survey research,* Emerald Publishing Group, UK.

Kulik, L., (2007), 'Explaining responses to volunteering: an ecological model', *Nonprofit and Voluntary Sector Quarterly*, **36**(2): 239-255.

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Jimenez, B., Miller, K., Oki, T., Şen, Z. & Shiklomanov, I., (2008), 'The implications of projected climate change for freshwater resources and their management', *Hydrological Sciences Journal*, **51**(1): 3-10.

Lam, Q. D., Schmalz, B. & Fohrer, N., (2010), 'Modelling point and diffuse source pollution of nitrate in a rural lowland catchment using the SWAT model', *Agricultural Water Management*, **92**(2): 317-325.

Landcare Trust, (2013), 'About us', retrieved 21 March, 2013 from http://www.landcare.org.nz/About-Us.

Larned, S. T., Scarsbrook, M. R., Snelder, T. H., Norton, N. J. & Biggs, B. J. F., (2004), 'Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land-cover classes', *New Zealand Journal of Marine and Freshwater Research*, **38**: 347-366.

Leach, M., (1992), 'Gender and the environment: traps and opportunities', *Development in Practice*, **2**(1): 12-22.

Li, Y. & Ferraro, K. F., (2006), 'Volunteering in middle and later life: is it a health benefit, barrier or both?', *Social Forces*, **85**(1): 497-519.

Mallin, M. A., Johnson, V. L. & Ensign, S. H. (2009), 'Comparative impacts of stormwater runoff on water quality of an urban, suburban, and a rural stream', *Environmental Monitoring and Assessment*, **159**: 475-491.

Mankin, K. R., Ngandu, D. M., Barden, C. J., Hutchinson, S. L. & Geyer, W. A., (2007), 'Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff', *Journal of the American Water Resources Association*, **43**(5): 1108-1116.

Maybeck, M., Kimstach, V. & Helmer, R., (1996), 'Strategies for water quality assessment', in Chapman, D. (ed), *Water Quality Assessments: a guide to use of biota, sediments and water in environmental monitoring*, University Press, Cambridge.

McLafferty, S. L., (2003), 'Conducting questionnaire surveys', in Clifford, N. J. & Valentine G. (eds), *Key Methods in Geography*, , Sage, London.

McLaren, S. J. & Kim, N. D., (1995), 'Evidence for a seasonal fluctuation of arsenic in New Zealand's longest river and the effect of treatment on concentrations in drinking water', *Environmental Pollution*, **90**(1): 67-73.

Means III, E. G., Ospina, L. & Patrick, R., (2005), 'Ten primary trends and their implications for water utilities', *Journal of the American Water Works Association*, **97**(7): 64-77.

Meredith, A. S. & Hayward, S. A., (2002), '*An overview of the water quality of the rivers and streams of the Canterbury Region*, Report No. R02/25, Environment Canterbury, Christchurch.

Miller, S. W., Wooster, D. & Li, J., (2007), 'Resistance and resilience of macroinvertebrates to irrigation water withdrawals', *Freshwater Biology*, **52**: 2494-2510.

Milly, P. C. D., Dunne, K. A. & Vecchia, A. V., (2005), 'Global pattern of trends in streamflow and water availability in a changing climate', *Nature*, **438**: 347–350.

Ministry for the Environment (2007), 'Environment New Zealand 2007', Ministry for the Environment, Wellington.

Ministry of Health, (2005), 'Drinking-water Standards for New Zealand 2005', Ministry of Health, Wellington.

Monaghan, R, M. & Smith, L. C., (2004), 'Minimising surface water pollution resulting from farm-dairy effluent application to mole–pipe drained soils. II. The contribution of preferential flow of effluent to whole-farm pollutant losses in subsurface drainage from a West Otago dairy farm', *New Zealand Journal of Agricultural Research*, **47**:417-428.

Monaghan, R. M., Wilcock, R. J., Smith, L. C., Tikkisetty, B., Thorrold, B. S. & Costall, D., (2007), 'Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand', *Agriculture, Ecosystems and Environment*, **118**: 211-222.

Morse, J. C., Bae, Y. J., Munkhjargal, G., Sangpradub, N., Tanida, K., Vshivkova, T. S., Wang, B., Yang, L. & Yule, C. M., (2007), 'Freshwater biomonitoring with macroinvertebrates in East Asia', *Frontiers in Ecology and the Environment*, **5**:33-42.

Moser, C. & Kalton, G., (2004), 'Questionnaires', in Seale, C. (ed), *Social Research Methods*, Routledge, London.

Nash, L., (1993), 'Water Quality and Health', in Gleick, P. H. (ed), *Water in Crisis: a Guide to the World's Fresh Water Resources*, Oxford University Press, New York.

Neal, C., Watts, C., Williams, R. J., Neal, M., Hill, L. & Wickham, H., (2002), 'Diurnal and longer term patterns in carbon dioxide and calcite saturation for the River Kennet, south-eastern England', *The Science of the Total Environment*, **282-283**: 205-231.

Nelson, K. C. & Palmer, M. A. (2007), 'Stream temperature surges under urbanisation and climate change: data, models, and responses', *Journal of the American Water Resources Association*, **43**: 440-452.

Nerbonne, J. F. & Vondracek, B., (2003), 'Volunteer macroinvertebrate monitoring: assessing training needs through examining error and bias in untrained volunteers', *Journal of the North American Benthological Society*, **22**(1): 152-163.

Nicholson, E., Ryan, J. & Hodgkins, D., (2002), 'Community data – where does the value lie? Assessing confidence limits of community collected water quality data', *Water Science and Technology*, **45**: 193-212.

O'Leary, N., Vawter, A. T., Wagenet, L. P. & Pfeffer, M., (2004), 'Assessing water quality using two taxonomic levels of benthic macroinvertebrate analysis: implications for volunteer monitors', *Journal of Freshwater Ecology*, **19**(4): 581-586.

Ouyang, Y., (2005), 'Evaluation of river water quality monitoring stations by principal component analysis', *Water Research*, **39**(12): 2621-2635.

Overdevest, C., Orr, C. H. & Stepenuck, K., (2004), 'Volunteer stream monitoring and local participation in natural resource issues', *Research in Human Ecology*, **11**(2): 177-185.

Ozkan, E., (1992), 'A survey of attitudes of applicators toward pesticide waste reduction', *Applied Engineering in Agriculture* 8(6): 771-776.

Parkhill, K. L. & Gulliver, J. S., (2002), 'Effect of inorganic sediment on whole stream productivity', *Hydrobiologia*, **472**: 5-17.

Parr, W. (1994), 'Water-quality monitoring', in Calow, P. & Petts, G. E. (eds), *The Rivers Handbook: hydrological and ecological principles, Volume Two*, Blackwell Scientific Publications, Oxford.

Paul, M. J. & Meyer, J. L., (2001), 'Streams and the urban landscape', *Annual Review of Ecology, Evolution and Systematic*s, **32**: 333-365.

Penrose, D., & Call, S. M., (1995), 'Volunteer monitoring of benthic macroinvertebrates: regulatory biologists' perspectives', *Journal of the North American Benthological Society*, **14**: 203: 209.

Pinheiro, J. C. & Bates, D. M., (2000), '*Mixed-Effects Models in S and S-PLUS*', Springer, New York.

Postel, S. L., Daily, G. C. & Ehrlich, P. R., (1996), 'Human appropriation of renewable fresh water', *Science*, **271**(5250): 785-788.

Potts, D. A., Görres, J. H., Nicosia, N. L. & Amador, J. A., (2004), 'Effects of aeration on water quality from septic system leachfields', *Journal of Environmental Quality*, **33**(5): 1828-1838.

Prud'homme, A., (2011), *The Ripple Effect: the fate of freshwater in the twenty-first century*, Scriber, New York.

Purcell, A. H., Friedrich, C. & Resh, V. H., (2002), 'An assessment of a small urban stream restoration project in Northern California', *Restoration Ecology*, **10**(4): 685-694.

Quinn, J. M. & Stroud, J. M., (2002), 'Water quality and sediment and nutrient export from New Zealand hill-land catchments of contrasting land use', *New Zealand Journal of Marine and Freshwater Research*, **36**: 409-429.

R Core Team, (2012), 'R: A language and environment for statistical computing', R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Rea, L. M. & Parker, R. A., (2005), 'Designing and conducting survey research: a comprehensive guide', Josey-Bass, San Francisco.

Reay, W. G., (2004), 'Septic tank impacts on ground water quality and nearshore nutrient flux', *Ground Water*, **42**(7): 1079-1089.

Reed, S. D, Grisso, R. D., Woldt, W. E. & Niemeyer, S. M., (2000), 'Waste assessment of agricultural chemicals, petroleum products and maintenance residuals on farmsteads', *Biological Systems Engineering: Papers and Publications*, Paper 181.

Ritter, L., Solomon, K., Sibley, P., Hall, K., Keen, P., Mattu, G. & Linton, B., (2002), 'Sources, pathways, and relative risks of contaminants in surface water and groundwater: a perspective prepared for the Walkerton Enquiry', *Journal of Toxicology and Environmental Health, Part A*, **65**: 1-142.

Rodgers, M., (2009), *Canterbury's Wicked Water: Politics, progress and prosperity imperilled*, CWW Solutions, Christchurch.

Rodgers, R., Soulsby, C., Hunter, C. & Petry, J., (2003), 'Spatial and temporal bacterial quality of a lowland agricultural stream in northeast Scotland', *Science of the Total Environment*, **314-316**: 289-302.

Roni, P., Fayran, A. H. & Miller, M. A., (2005), 'Monitoring and evaluating instream habitat enhancement', in Roni, P. (ed), *Monitoring Stream and Watershed Restoration*, American Fisheries Society, Bethesda.

Royle, J. A., (2004), 'Modelling abundance index data from Anuran calling surveys', *Conservation Biology*, **18**(5): 1378-1385.

Ryan, R. L., Rachel, K. & Grese, R. E., (2001), 'Predicting volunteer commitment in environmental stewardship programmes', *Journal of Environmental Planning and Management*, **44**(5): 629-648.

Scarsbrook, M., (2006), 'State and Trends in the National River Water Quality Network (1989–2005)', Ministry for the Environment, Wellington.

Schmid, A. N., Thompson, J. R. & Bengston, D. N., (2007), 'The public discourse about land use and water quality: themes in newspapers in the Upper Mississippi River Basin', *Applied Environmental Education and Communication*, **6**: 187-196.

Schoonover, J. E., Lockaby, B. G. & Pan, S., (2005), 'Changes in chemical and physical properties of stream water across an urban-rural gradient in western Georgia', *Urban Ecosystems*, **8**: 107-124.

Sharpe, A. & Conrad, C., (2006), 'Community based ecological monitoring in Nova Scotia: challenges and opportunities', *Environmental Monitoring and Assessment*, **113**: 395-409.

Sheridan, A., (2007), 'The Wakapuaka River: the story of the river running through our lives', Wakapuaka Rivercare Group, Nelson.

Shiklomanov, I. A., (2000), 'Appraisal and assessment of world water resources', *Water International*, **25**(1): 11-32.

Showers, W. J., Genna, B., McDade, T., Bolich. R. & Fountain, J. C., (2008), 'Nitrate contamination in groundwater on an urbanised dairy farm', *Environmental Science and Technology*, **42**(13): 4683-4688.

Silvano, R. A. M., Udvardy, S., Ceroni, M. & Farley, J., (2005), 'An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management', *Ecological Economics,* **53**: 369-385.

Smith Jnr, J. E. & Perdek, J. M., (2004), 'Assessment and management of watershed microbial contaminants', *Critical Reviews in Environmental Science and Technology*, **34**: 109-139.

Smith, J. D., (1999), 'Poor marketing or the decline of altruism? Young people and volunteering in the United Kingdom', *International Journal of Nonprofit and Voluntary Sector Marketing*, **4**(4): 372-377.

Smith, L. C. & Monaghan, R. M., (2003), 'Nitrogen and phosphorus losses in overland flow from a cattle-grazed pasture in Southland', *New Zealand Journal of Agricultural Research*, **46**: 225-238.

Spellman, F. R., (2008), *The Science of Water: Concepts and Applications*, CRC Press, Florida.

Stevenson, M., Wilks, T. & Hayward, S., (2010), *An overview of the state and trends in water quality of Canterbury's rivers and streams*, Report No. R10/117, Environment Canterbury, Christchurch.

Strobl, R. O. & Robillard, P. D., (2008), 'Network design for water quality monitoring of surface freshwaters: a review', *Journal of Environmental Management*, **87**(4): 639-648.

Stukas, A. A., Worth, K. A., Clary, E. G. & Snyder, M., (2009), 'The matching of motivations to affordances in the volunteer environment: and index for assessing the impact of multiple matches on volunteer outcomes', *Nonprofit and Voluntary Sector Quarterly*, **35**(1): 5-28.

Styx Living Laboratory Trust, (2013) a, 'Styx Project', retrieved 20 November, 2012, from http://www.thestyx.co.nz/new-zealand/visionone/

Styx Living Laboratory Trust, (2013) b, 'Issues', retrieved 20 November, 2012, from http://www.thestyx.co.nz/new-zealand/issues/

Styx Living Laboratory Trust, (2013) c, 'Styx Mill Conservation Reserve', retrieved 27 November, 2012, from http://www.thestyx.co.nz/new-zealand/styx_mill_conservation_reserve/

Suren, A., (2012), 'The invertebrate communities of the Styx River: summary of monitoring programme 2006-2012, and recommendations for future work', retrieved 4 April, 2013, from http://www.thestyx.co.nz/content/library/Final_Styx_Invertebrate_Report.pdf

Suthar, S., Bishoni, P., Singh, S., Mutiyar, P. K., Nema, A. K., Patil, N. S. (2009), 'Nitrate contamination in groundwater of some rural areas of Rajasthan, India', *Journal of Hazardous Materials*, **171**: 181-199.

Svendsen, E. S. & Campbell, L. K., (2008), 'Urban ecological stewardship: understanding the structure, function and network of community-based urban land management', *Cities and the Environment*, **1**(1): 1-31.

Tadesse, I., Green, F. B. & Puhhakka, J. A., (2004), 'Seasonal and diurnal variations of temperature, pH and dissolved oxygen in advanced integrated wastewater pond system® treating tannery effluent', *Water Research*, **38**: 645-654.

Taniguchi, H., (2006), 'Men's and Women's Volunteering: Gender Differences in the Effects of

Tasman District Council, (2012), 'Wakapuaka at Hira – River Flow', retrieved 28 November, 2012, from http://www.tasman.govt.nz/environment/water/rivers/river-flow/riverflow-220/

Thomas, L., (1997), 'Retrospective power analysis', *Conservation Biology*, **11**: 276-280.

Tipa, G. & Teirney, L., (2003), 'A Cultural Health Index for Streams and Waterways: Indicators for recognising and expressing Maori values', Ministry for the Environment, Wellington.

Tipa, G. & Teirney, L., (2006), 'Cultural Health Index for Streams and Waterways: a tool for nationwide use', Ministry for the Environment, Wellington.

Tu, J., Xia, Z-G., Clarke, K. C. & Frei, A. (2007), 'Impact of urban sprawl on water quality in eastern Massachusetts, USA', *Environmental Management*, **40**: 183-200.

United Nations Conference on Environment and Development, (1993), 'Agenda 21 – Programme of Action for Sustainable Development', United Nations, New York.

United States Environmental Protection Agency, (2012), 'EPA's Volunteer Monitoring Program', retrieved 26 November, 2012, from http://water.epa.gov/type/rsl/datait/waters/georef/epasvmp.cfm

Van Wezel, A., Mons, M. & van Delft, W., (2010), 'New methods to monitor emerging chemicals in the drinking water production chain', *Journal of Environmental Monitoring*, **12**: 80-89.

Vaughan, H., Whitelaw, G., Craig, B. & Stewart, C., (2003), 'Linking ecological science to decision-making: delivering environmental monitoring information societal feedback', *Environmental Monitoring and Assessment*, **88**: 399-408.

Veuthey, S. & Gerber, J., (2010), 'Logging conflicts in Southern Cameroon: a feminist ecological economics perspective', *Ecological Economics*, **70**(2): 170-177.

Wai Care, (2003), 'Book 1: Wai Care Starter Pack', Wai Care, Auckland.

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M. & Morgan R. P II, (2005), 'The urban stream syndrome: current knowledge and the search for a cure', *Journal of the North American Benthological Society*, **24**(3): 207-273.

Wang, S. & Mulligan, C. N., (2006), 'Occurrence of arsenic contamination in Canada: Sources, behaviour and distribution', *Science of the Total Environment*, **366**: 701-721.

Wang, X., (2005), 'Diffuse pollution from livestock production in China', *Chinese Journal of Geochemistry*, **24**(2): 189-193.

Warburton, J. & Gooch, M., (2007), 'Stewardship volunteering by older Australians: the generative response', *Local Environment: The International Journal of Justice and Sustainability*, **12**(1): 43-55.

Warburton, J., Paynter, J. & Petriwskyj A., (2007), 'Volunteering as a productive aging activity: incentive and barriers to volunteering by Australian Seniors', *Journal of Applied Gerontology*, **26**: 333-355.

Weisberg, H. F., Krosnick, J. A. & Bowen, B. D., (1996), 'An Introduction to Survey Research, Polling, and Data Analysis, Third Edition', Sage, California.

Welch, A. H., Lico. M. S & Hughes, J. L., (1988), 'Arsenic in ground water in the western United States', *Ground Water*, **26**(3): 333-347.

Westbrook, S. J., Rayner, J. L., Davis, G. B., Clement, T. P., Bjerg, P. L. & Fisher, S. J., (2005), 'Interaction between shallow groundwater, saline surface water and contaminant discharge at a seasonally and tidally forced estuarine boundary', *Journal of Hydrology*, **302**: 255-269.

Whitelaw, G., Vaughan, H., Craig, B. & Atkinson, D., (2003), 'Establishing the Canadian Community Monitoring Network', *Environmental Monitoring and Assessment,* **88**: 409-418.

Wilcock, R. J., Monaghan, R. M., Quinn, J. M., Campbell, A. M., Thorrold, B. S., Duncan, M. J., McGowan, A. W. & Betteridge, K., (2006), 'Land-use impacts and water quality targets in the intensive dairying catchment of the Toenepi Stream, New Zealand', *New Zealand Journal of Marine and Freshwater Research*, **40**: 123-140.

Wilson, J., (2000), ‘Volunteering’, *Annual Review of Sociology*, **26**: 215-240.

Wilson, N. & Webster-Brown, J., (2009), ‘The fate of antimony in a major lowland river system, the Waikato River, New Zealand’, *Applied Geochemistry*, **24**: 2283-2292.

Winterbourn M. J. & Collier, K. J., (1987), ‘Distribution of benthic invertebrates in acid, brown water streams in the South Island of New Zealand’, *Hydrobiologia*, **153**: 277-286.

Wood, P. J. & Armitage, P. D., (1997), ‘Biological effects of fine sediment in the lotic environment’, *Environmental Management*, **21**(2): 203-217.

Yanay, G. V. & Yanay N., (2008), ‘The decline of motivation? From commitment to dropping out of volunteering’, *Nonprofit Management and Leadership*, **19**(1): 65-78.

Yarnell, P. & Gayton D. V., (2003), ‘Community-based ecosystem monitoring in British Columbia: a survey and recommendations for extension’, FORREX – Forest Research Extension Partnership, Kamloops, British Columbia, FORREX series 13.

Young, R., Quaterman, A. J., Eyles, R. F., Smith, R. A. & Bowden, W. B., (2005), ‘Water quality and thermal regime of the Motueka River: influences of land cover, geology and position in the catchment’, *New Zealand Journal of Marine and Freshwater Research*, **39**: 803-825.

Zar, J., (2010), *Biostatistical Analysis (5th edn)*, Prentice Hall, New Jersey.

Zimmerman, J. B., Mihelcic, J. R. & Smith, J., (2008), ‘Global stressors on water quality and quantity’, *Environmental Science and Technology*, **42**(12): 4247-4254.

Appendix 1: The Survey

This is the base survey, questions 4-8 were altered to include the name of the group the volunteers belonged to.

1. Age: ≤20 21-25 25-30 31-40 41-50 51-60 61-70 71+
2. Female/Male
3. Occupation:
4. How long have you been involved with the Styx Living Laboratory Trust (SLLT)?
5. Do you live within the catchment of the Styx River? (See map)
   If no, which area/suburb to you live in? And if there was a programme such as the SLLT in operating in the catchment you live in, would you rather volunteer for them or remain helping the SLLT?
6. How did you find out about the SLLT?
7. Why did you choose to become involved with the SLLT?
8. What did you hope to achieve by becoming involved with community monitoring with the SLLT?
9. Do you feel you have achieved this? Why?
10. Do you think there are any parts of the volunteer experience (for example educational opportunities or explanations) that can be improved? If yes, how?
11. What do you think the purpose of the monitoring is?
12. What do you think the data collected **IS** used for?
13. What do you thing the data collected **COULD BE** used for?
14. Do you consider the data collected to be of a quality high enough for use in planning, decision making and scientific study? Why?
15. List the water quality parameters that you measure during each field session
16. Explain (if you can) what each parameter tells us about the water quality
17. Do you think there are any aspects of the monitoring procedures that can be improved? If yes, how?
18. Are you involved with any other environmental groups? If yes, what are they?
19. What do you think are the main issues New Zealand faces with regard to its **FRESHWATER RESOURCES**?
20. What do you think are the main issues New Zealand faces with regard to the **ENVIRONMENT AS A WHOLE**?

Appendix 2: LME results

Linear mixed effects model results for pH. The AIC value for the most parsimonious model, including significant two and three way interactions was 611.136.

	Effect	Std Error	DF	t value	P value
Intercept	29.792	4.363	650	6.828	<0.001 *
Date	0.000	0.000	650	-5.300	<0.001 *
Time	-0.012	-0.012	650	-2.604	0.009 *
Distance from mouth	0.000	0.000	8	-2.825	0.022 *
Rainfall in last 24 hrs	0.062	0.062	650	0.621	0.535
Water temperature	-0.029	-0.029	650	-1.285	0.199
Conductivity	-0.229	-0.229	650	-6.782	<0.001 *
Clarity	-0.004	-0.004	650	-3.215	0.001 *
Date * time	0.000	0.000	650	2.975	0.003 *
Date * conductivity	0.000	0.000	650	6.650	<0.001 *
Date * time * distance from mouth	0.000	0.000	650	2.711	0.007 *
Date * time * conductivity	0.000	0.000	650	-5.139	<0.001 *
Date * distance from mouth * rainfall in last 24 hrs	0.000	0.000	650	-3.551	<0.001 *
Date * distance from mouth * conductivity	0.000	0.000	650	2.213	0.027 *
Distance from mouth * rainfall in last 24 hrs * water temperature	0.000	0.000	650	1.358	0.175
Distance * rainfall in last 24 hrs * conductivity	0.000	0.000	650	1.735	0.083 .

Linear mixed effect model results for conductivity. The AIC for this model, the most parsimonious is 5740.459.

	Value	Std Error	DF	t value	P value
Intercept	805.805	148.213	646	5.437	<0.001 *
Date	-0.358	0.070	646	-5.089	<0.001 *
Time	-0.676	0.195	646	-3.458	<0.001 *
Rainfall in last 24 hrs	1.747	3.683	646	0.475	0.635
Distance from mouth	-0.004	0.001	8	-3.718	0.006 *
Water temperature	-15.161	2.721	646	-5.572	<0.001 *
pH	-83.728	23.151	646	-3.617	<0.001 *
Clarity	0.283	0.308	646	0.920	0.358
Date * time	0.000	0.000	646	4.389	<0.001 *
Date * pH	0.058	0.011	646	5.229	<0.001 *
Time * water temperature	0.012	0.003	646	4.416	<0.001 *
Time * pH	0.098	0.031	646	3.159	0.002 *
Distance from mouth * water temperature	0.000	0.000	646	2.964	0.003 *
Water temperature * clarity	0.028	0.019	646	1.456	0.146
Date * time * pH	0.000	0.000	646	-4.610	<0.001 *
Date * rainfall in last 24 hrs * distance from mouth	0.000	0.000	646	-1.467	0.143
Time * pH * clarity	0.000	0.000	646	2.736	0.006 *
Date * time * distance from mouth * pH	0.000	0.000	646	-1.984	0.048 *
Time * rainfall in last 24 hrs * distance from mouth * water temperature	0.000	0.000	646	-1.830	0.068 .

Results from the linear mixed effect model for water temperature. The AIC for this model, the most parsimonious is 2923.106.

	Value	Std Error	DF	t value	P value
Intercept	-50.401	25.022	650	-2.014	0.044 *
Date	0.026	0.012	650	2.236	0.026 *
Time	0.011	0.004	650	2.942	0.003 *
Rainfall in last 24 hrs	-0.625	2.267	650	-0.276	0.783
Distance from mouth	0.000	0.000	8	-2.796	0.023 *
Clarity	0.062	0.031	650	1.986	0.047 *
Conductivity	0.531	0.203	650	2.616	0.009 *
pH	11.087	4.033	650	2.749	0.006 *
Date * distance from mouth	0.000	0.000	650	2.784	0.006 *
Date * pH	-0.005	0.002	650	-2.570	0.010 *
Date * conductivity	0.000	0.000	650	-2.521	0.012 *
Time * rainfall in last 24 hrs	-0.005	0.001	650	-3.963	<0.001 *
Time * clarity	0.000	0.000	650	-1.467	0.143
Distance from mouth * conductivity	0.000	0.000	650	1.609	0.108
Rainfall in last 24 hrs * pH	0.649	0.383	650	1.695	0.091 .
Conductivity * pH	-0.102	0.033	650	-3.074	0.002 *
Date * conductivity * pH	0.000	0.000	650	2.778	0.006 *

Linear mixed effects model results for clarity. This was the most parsimonious model given by the AIC value 5393.188.

	Value	Std Error	DF	t value	P value
Intercept	83.209	30.787	653	2.703	0.007 *
Date	-0.019	0.006	653	-3.189	0.002 *
Time	0.111	0.037	653	2.978	0.003 *
Distance from mouth	0.000	0.000	8	0.064	0.951
Rainfall in last 24 hrs	-10.131	4.522	653	-2.240	0.025 *
Water temperature	-0.116	2.020	653	-0.058	0.954
pH	-3.837	1.312	653	-2.925	0.004 *
Conductivity	0.009	0.184	653	0.051	0.959
Date* time	0.000	0.000	653	2.393	0.017 *
Time * water temperature	-0.003	0.002	653	-2.122	0.034 *
Date * conductivity	0.000	0.000	653	2.888	0.004 *
Time * conductivity	-0.001	0.000	653	-3.741	0.002 *
Water temperature * conductivity	0.025	0.013	653	1.855	0.064 .
Rainfall in last 24 hrs * water temperature * conductivity	0.004	0.003	653	1.543	0.123